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**Draft Work Plan for an
Engineering Evaluation/Cost Analysis
in Support of the Risk-Based Approach
to Remediation at Pumphouse #2**



**Malmstrom Air Force Base
Great Falls, Montana**

Prepared For

**Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas**

and

**Malmstrom Air Force Base
Great Falls, Montana**

August 1994

ENGINEERING-SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290

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SECTION 1

INTRODUCTION

This work plan was prepared by Engineering-Science, Inc. (ES) and describes the scope of work required for the collection and analysis of data to complete an engineering evaluation/cost analysis (EE/CA) in support of a risk-based remediation decision for soil and ground water contaminated with fuel hydrocarbons at Pumphouse #2 at Malmstrom Air Force Base (AFB), Great Falls, Montana. Under the basewide Installation Restoration Program (IRP), Pumphouse #2 is a portion of Site PS-3 and may be referred to as such in referenced documents used in preparation of this work plan. This work plan is the equivalent of a treatability study test design (TSTD) for the field test of the risk-based approach to remediation at Pumphouse #2. This innovative technology is sponsored by the Air Force Center for Environmental Excellence (AFCEE) at Brooks AFB, Texas, under contract F41624-93-C-8044, "Risk-Based Approach to Fuel Spill Remediation." The Pumphouse #2 demonstration is a component of a multi-site initiative being sponsored by AFCEE to demonstrate how quantitative fate and transport calculations and risk information based on site-specific data can be integrated to quickly determine the type and magnitude of remedial action required at a site to minimize contaminant migration and receptor risks.

1.1 GOALS AND OBJECTIVES

The risk-based approach is designed to combine natural, or intrinsic, remediation with low-cost source removal technologies such as *in situ* bioventing to economically reduce risks posed by subsurface petroleum spills. There are three primary goals of this demonstration project. The first goal is to determine if remedial actions are necessary to minimize contaminant migration and potential receptor exposure to fuel-hydrocarbon-contaminated environmental media at Pumphouse #2. The second goal is to implement any necessary and appropriate remedial technologies at Pumphouse #2. It is possible that at some fuel-contaminated sites, intrinsic remediation alone will be sufficient to minimize or eliminate potential risks to human health and the environment. Implementation of the intrinsic remediation option under these circumstances would require only long-term monitoring to confirm the effectiveness of this remediation approach. At other sites, however, it may be necessary to supplement intrinsic remediation and long-term monitoring with some type of engineered solution, such as source removal, to minimize contaminant migration and receptor exposure. A combination of removal (e.g., free product recovery and bioventing), intrinsic remediation, and/or administrative commitments (e.g., long-term monitoring, land use restrictions) constitute a remedial alternative. The third goal is to collect data on how best to implement a risk-based remediation at the site, which will eventually be incorporated into a programmatic protocol document on the risk-based approach.

This protocol document will standardize site characterization, modeling, and interpretive procedures. Lessons learned and case studies developed as part of this demonstration program will be factored into the protocol document to illustrate how best to complete a risk-based remediation of a site.

The specific objective of the work described herein is to develop an EE/CA that identifies and evaluates an appropriate remedial alternative for contaminated environmental media at Pumphouse #2 at Malmstrom AFB, Montana, that will be protective of human health and the environment. ~~This~~ ^{The} EE/CA is intended to provide sufficient evidence to select and implement an appropriate remedial alternative to reduce risks associated with chemical contamination at Pumphouse #2. The underlying tenet of this project will be to close/remediate, remove, decontaminate, and/or control all waste, waste residues, leachate, and contaminated media to levels and in a manner such that any substantial present or future threat to human health or the environment is eliminated or reduced to the maximum extent practicable. This work plan describes the specific site characterization activities and data analyses which will be performed in support of the EE/CA and the risk-based approach to remediation for Pumphouse #2.

1.2 SCOPE OF WORK

The major milestones of this demonstration project are as follow: (1) gather site-specific data on the nature and extent of contamination in the soil, ground water, and surface water at Pumphouse #2; (2) determine whether an unacceptable risk to human health or the environment currently exists or may occur in the foreseeable future using quantitative contaminant transport models and risk estimates; and (3) evaluate, recommend, design, construct, and operate an innovative remedial alternative that both reduces the source of contamination and minimizes or eliminates potential risks to human health and the environment due to exposure to Pumphouse #2 contamination. These major milestones are briefly described in this section and illustrated in Figure 1.1.

1.2.1 Determining Contaminant Distribution

The risk-based approach to remediation for Pumphouse #2 is designed to provide risk reduction to levels that are protective of human health and the environment through the use of a remedial alternative that is permanent or has a high degree of long-term effectiveness. The EE/CA report prepared as part of this field test of an innovative technology will evaluate and integrate site-specific data using streamlined risk assessment procedures to develop and determine final site-specific cleanup levels. It is the intent of the Air Force to demonstrate a risk-based remediation approach for Pumphouse #2. Therefore, site characterization efforts will involve identifying the principal risks at the site which must be addressed by a combination of source removal, intrinsic remediation, and long-term monitoring.

Site characterization studies in support of the risk-based approach for Pumphouse #2 will consider the four primary contaminant phases associated with subsurface fuel hydrocarbon contamination:

- Vapors in the soil gas of the vadose zone soils;
- Residual fuel in the vadose zone (unsaturated) soils;

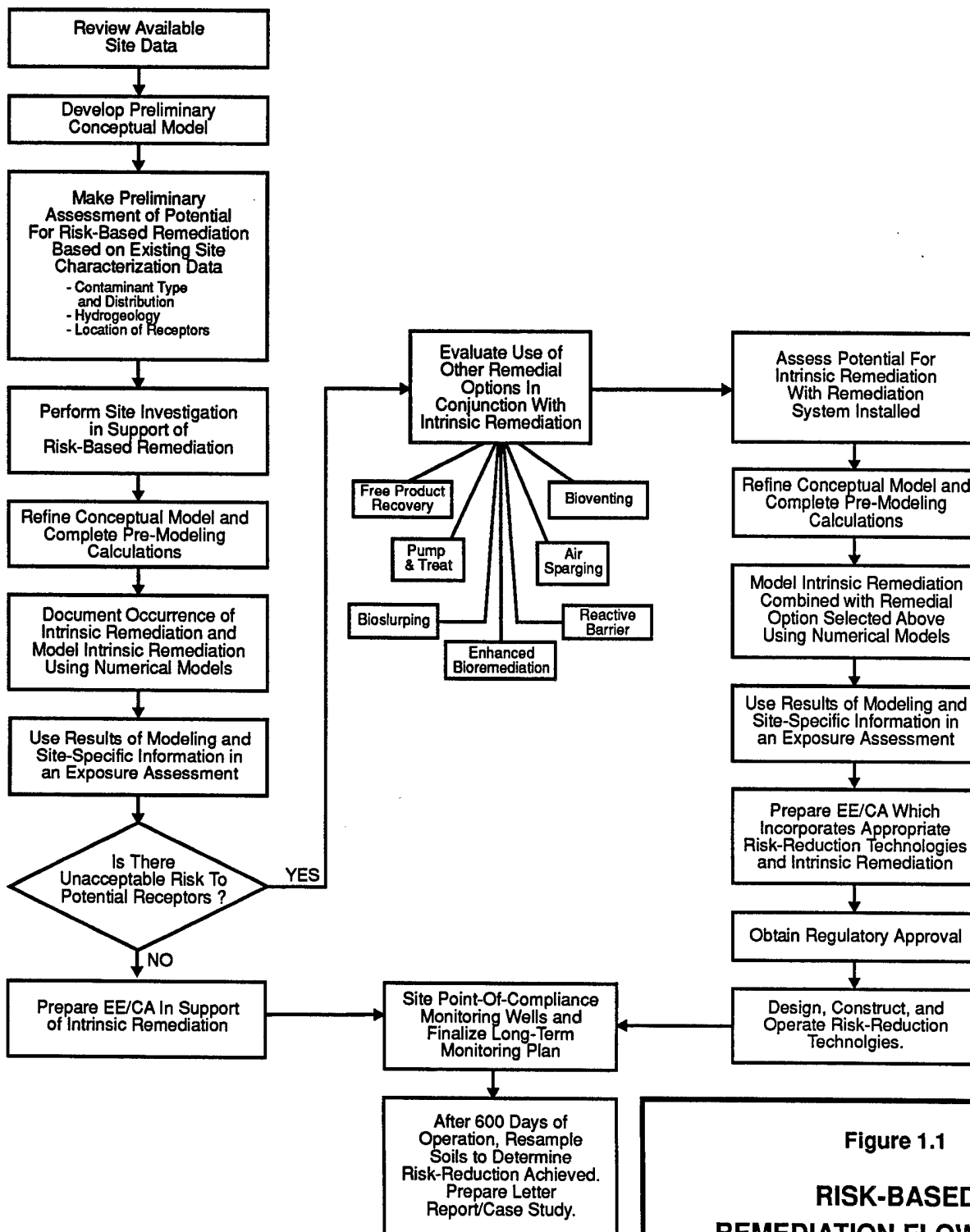


Figure 1.1
**RISK-BASED
REMEDATION FLOW CHART**

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

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- Free-phase product floating on the ground water; and
- Dissolved-phase fuel contaminants in the ground water.

Volatilization and upward molecular diffusion of fuel hydrocarbon contamination can result in measurable concentrations of hydrocarbons in the vadose zone soil gas and abovegrade atmosphere. If present in sufficient quantities, fuel will spread downward and laterally through the vadose zone soils, leaving residual fuel in the vadose zone which can create a long-term ground water contaminant source (Abdul, 1988; American Petroleum Institute, 1980). Gradual partitioning of fuel contaminants from either the free-phase source or the residual fuel product in vadose zone soil into ground water results in a dissolved-phase contaminant plume that can migrate downgradient under the influence of mass transport processes (e.g., Domenico and Schwartz, 1990). If contaminated ground water discharges into a surface water body, dissolved-phase hydrocarbons may also contaminate the surface water. Site characterization activities for Pumphouse #2 will include sampling of soil, soil gas, surface water or sediment, and ground water. Sufficient samples will be collected and analyzed to assess the risk to human health and the environment and to demonstrate attainment of site-specific risk-based cleanup levels. Section 4 of this work plan provides additional details on site characterization data needed to support a risk-based approach to remediation at Pumphouse #2.

1.2.2 Estimating Potential Risks to Human Health and the Environment

The risk-based approach to remediation is dependent on conservatively estimating levels of residual fuel that can remain onsite and not pose an unacceptable risk to human health or the environment. The risk-based approach to remediation allows site-specific flexibility in determining which potential remedial alternatives afford the highest degree of long-term effectiveness appropriate for the current and future uses of the site. The US Environmental Protection Agency (EPA) recognizes that the mere presence of a contaminant does not necessarily warrant remediation, and that the goal of remediation investigations is to determine what remedial actions are necessary to eliminate or minimize risks to human health and the environment (EPA, 1987). Using site-specific data, a quantitative source-and-release analysis and an exposure pathway analysis will be completed to determine which if any of the four contaminant phases (i.e., soil gas, contaminated vadose zone soils, free-phase product, and dissolved-phase contamination) may pose a risk to human health and the environment. Quantitative contaminant fate and transport models such as Bioplume II (Rifai et al., 1988) will be used to determine whether fuel contaminants could migrate to a potential receptor exposure point. This is one of the key steps in the risk-based approach to remediation because it ensures that costly engineered solutions are not employed at a site which does not and will not pose a risk to human health and the environment.

However, in the event that site data indicate that contamination from Pumphouse #2 could migrate to a potential receptor exposure point, site-specific, risk-based cleanup goals will be developed using well-defined quantitative procedures to determine the cleanup levels necessary for each medium to eliminate or minimize current and potential future risks to human and ecological receptors. These quantitative risk-based cleanup goals will be used to assess whether it will be necessary to supplement intrinsic remediation with an engineered remediation technology to minimize or eliminate potential risks.

The risk-based approach to remediation is not intended to replace a traditional baseline risk assessment where the final decision is whether remedial actions are necessary (EPA, 1989b). A baseline risk assessment will not be necessary at sites to be addressed using the risk-based approach, as it has already been determined that some remedial action will be taken. The risk-based approach is more analogous to an evaluation of the long-term risks associated with implementing a specific remedial action at a site (EPA, 1991b). This innovative approach streamlines the remedial decision process by focusing data collection and evaluation on identifying which remedial action most cost effectively reduces potential risks to human health and the environment. The risk-based approach compresses the traditional multistep remediation process into one project with the intent of quickly and cost effectively reducing any risks associated with chemical contamination at or migrating from Pumphouse #2.

A quantitative, iterative process will be used to assess the potential effectiveness of various remedial alternatives (e.g., intrinsic remediation alone vs. various source removal options coupled with intrinsic remediation) in minimizing contaminant migration and receptor exposure. Chemical-specific, risk-based cleanup levels will be derived using site-specific data and quantitative human health-based risk assessment procedures whenever a chemical-specific standard or alternate concentration is not available or appropriate. These risk-based cleanup levels will incorporate data on technical limitations, effectiveness, practicability, and other relevant features of the various remedial alternatives considered appropriate for the site. These cleanup levels will be factored into the final design of an appropriate remedial action for Pumphouse #2. Sections 2 and 5 of this work plan provide more detail on how human health and environmental risks associated with various remedial alternatives considered for Pumphouse #2 will be evaluated as part of this demonstration.

1.2.3 Developing an Appropriate Remedial Approach

The risk-based approach for the remediation of Pumphouse #2 is intended to quickly define a remedial alternative that will reduce or eliminate significant risks to human health and/or the environment. Identification and evaluation of any remedial technology, including intrinsic remediation, will be based on an evaluation of (1) long-term effectiveness; (2) permanence; (3) ability to reduce contaminant toxicity, mobility, or volume; (4) implementability; and (5) cost. The EE/CA must provide sufficient technical data on the recommended remedial alternative to show that it eliminates or abates present and future threats to human health and the environment, and that appropriate long-term commitments such as long-term monitoring are designed to supplement intrinsic remediation or any engineering controls.

A key objective of this evaluation will be to determine potential short- and long-term risks to the community and site workers. Determining how effective any one remedial technology may be at achieving desired protective remediation levels will require application of data from past treatability studies, an understanding of governing contaminant fate and transport processes, and engineering judgment. Both quantitative and qualitative analyses will be completed in support of the selection and design of an appropriate remedial action for the site. Long-term monitoring as part of this field test of an innovative technology will likely involve the installation and sampling of confirmation, point-of-compliance (POC), and other monitoring wells. Confirmation wells will be located immediately downgradient of the existing plume (i.e., within 1 or 2 years) and will provide for early confirmation of model and engineering predictions. The POC wells will be

located further downgradient (e.g., along the property boundary; at a location approximately 5 years downgradient of the current plume; 1 or 2 years upgradient of the nearest potential ground water receptor) to verify that site-related contamination does not pose an unacceptable risk to potential receptors over time. The location of POC wells will be established in concert with regulatory authorities to be protective of any potential receptor. Other wells that can be used to monitor the effectiveness of a ground water remediation over time will at least include one well upgradient of the contaminant plume, one well within the anaerobic zone, and one well within the aerobic treatment zone. The final number and location of wells to be included in a long-term monitoring program will depend on hydrogeologic, risk, and other regulatory considerations. Any requirements for long-term commitments to protect human health and the environment will be clearly described in the EE/CA. Requirements for long-term monitoring will be dependent upon the permanence or degree of long-term effectiveness afforded by the recommended remedial alternative.

Evaluation of remedial technologies as part of this field test will also focus on whether the technology can readily and economically achieve desired remediation levels and what uncertainties may be involved in this determination. Details on implementability with respect to expected time to achieve desired remediation levels will be factored into the evaluation. Identifying and assessing specific remedial technologies will also provide valuable information on which technologies will be less effective in risk reduction at Pumphouse #2.

The risk-based approach to remediation should streamline the remedial decision-making process by providing sufficient data to support the selection, design, and implementation of a low-cost final remedial alternative for Pumphouse #2 that will minimize contaminant migration and potential receptor exposure. The streamlined process should also reduce the amount of time between identification of a potential risk to human health and the environment and remediation of that risk. Additionally, site data to be collected will assist in subsequent risk analysis and remedial design efforts for other contaminated areas at Malmstrom AFB by quantifying source release and transport mechanisms in local soils and ground water. This information will assist in the evaluation of the effectiveness of other remedial technologies.

1.3 WORK PLAN ORGANIZATION

This work plan is oriented toward the collection of site-specific data to be used to complete quantitative analyses of contaminant migration potential and the potential risks associated with contaminant migration. This work plan describes the need for additional data and how that data will be collected in the field and then analyzed using contaminant fate and transport models such as Bioplume II. Data from completed and ongoing treatability studies, such as the bioventing pilot test, will be used both to characterize the current nature and extent of potential source contamination and to estimate the effectiveness of additional source removal activities at Pumphouse #2, should such measures be necessary to minimize future contaminant migration and receptor exposure. This work plan also describes the methods of risk analysis that will be used to identify and develop remedial actions for Pumphouse #2. This work plan was prepared to coordinate the activities of all agencies involved in this risk-based demonstration, including AFCEE, Malmstrom AFB, the EPA, the State of Montana Department of Health and Environmental Sciences, and ES.

This work plan is based on a review of existing site characterization data and the data needs of the risk-based approach to remediation. The work plan consists of seven sections, including this introduction. Section 2 summarizes existing data on the physical characteristics and nature and extent of contamination at Pumphouse #2. Section 3 presents a conceptual site model that will aid in defining necessary site characterization activities and subsequent data analyses. Section 4 describes the data needs of the risk-based approach to remediation for Pumphouse #2. The proposed sampling strategy for the collection of additional site characterization data is presented. Section 5 discusses the proposed risk analysis methods and the EE/CA report format. Section 6 includes a proposed schedule defining milestone dates for the demonstration project at Pumphouse #2. Section 7 contains the references used in preparing this document. This work plan also contains two appendices. Appendix A is the detailed site-specific sampling and analysis plan (SAP). Appendix B is the site-specific health and safety plan which is an addendum to the risk-based program health and safety plan (ES, 1994).

SECTION 2

REVIEW OF AVAILABLE SITE DATA

Existing site-specific data were used to describe the physical characteristics of environmental media and the nature and extent of contamination at Pumphouse #2. Review of available site data will aid in defining the additional site characterization data necessary to fill current data gaps, support quantitative modeling efforts, develop long-term risk-based cleanup levels, and evaluate, select, and implement the most cost-effective remedial alternative for the site.

2.1 SITE BACKGROUND

Malmstrom AFB is located in north-central Montana approximately 5 miles east of the City of Great Falls (Figure 2.1). A fuel storage and pumping facility, also referred to as Pumphouse #2, is located in the northern portion of the base, just off the flightline. Figure 2.2 shows the location of Pumphouse #2 on Malmstrom AFB. Pumphouse #2 along with another pumphouse, Pumphouse #3, and the hydrant refueling system under the aircraft apron comprise IRP Site PS-3. The majority of previous site investigations have encompassed the entire PS-3 area. However, this investigation will focus only on Pumphouse #2. The site consists of a pumphouse (Building 245), electrical control building (Building 246), and one 2,000-gallon and six 50,000-gallon underground storage tanks (USTs) (Figure 2.3). The 2,000-gallon tank was used to store waste fuel collected in Building 245 and is currently inactive. Four of the larger USTs are inactive, while the remaining two contain unleaded MOGAS and a deicing glycol solution. The five inactive tanks at the site were taken out of service in 1992 after failing tank integrity testing. The amount of fuel that has leaked from these seven tanks and associated piping is unknown. Future plans call for the removal of all building and tanks at Pumphouse #2 after new aboveground tanks are installed at another location on Malmstrom AFB (HDR, 1994). This removal action is currently scheduled for June 1995. ES will carefully coordinate all field activities with Malmstrom AFB to avoid conflict between the two activities at the site.

Pumphouse #2 has been characterized as a portion of Site PS-3 under the US Air Force IRP (JRB Associates, 1985; Battelle, 1988; and SAIC, 1991), a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) (Woodward-Clyde, 1992 and HDR, 1994), and as part of the bioventing pilot test program sponsored by AFCEE (ES, 1993). The results of these investigations indicate soil and ground water fuel hydrocarbon contamination at Pumphouse #2. A potential source of contamination at Pumphouse #2 was a leaking fuel transfer pipeline. Several underground pipelines pass through and adjacent to the area of the pumphouse and USTs. The contents and exact location of the leaking line have not been identified (HDR, 1994). Analysis of samples obtained during the IRP Phase II, Stage 1 and 2 investigations were interpreted by SAIC (1991) to indicate that the primary contaminant at the site was diesel fuel.

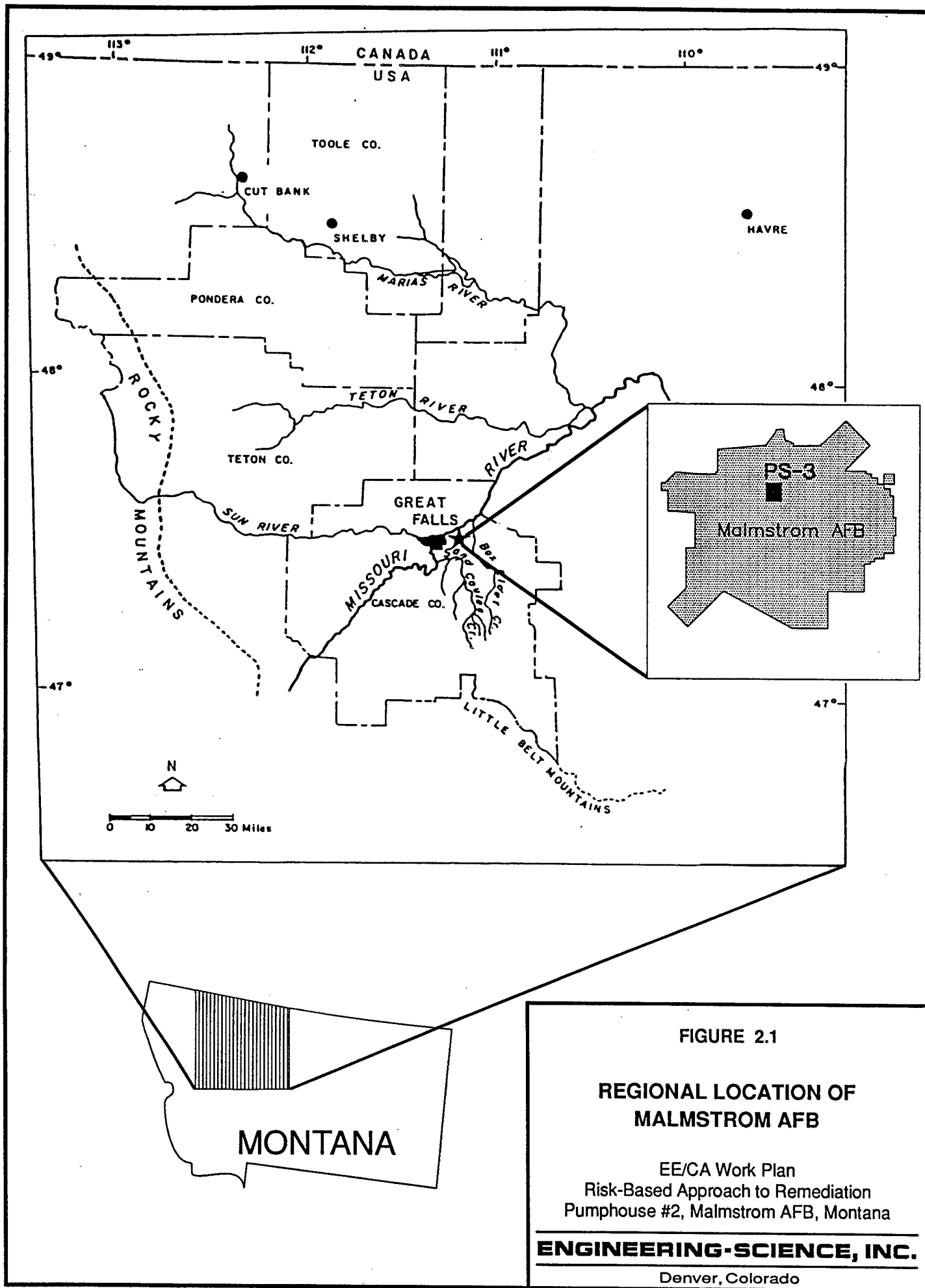


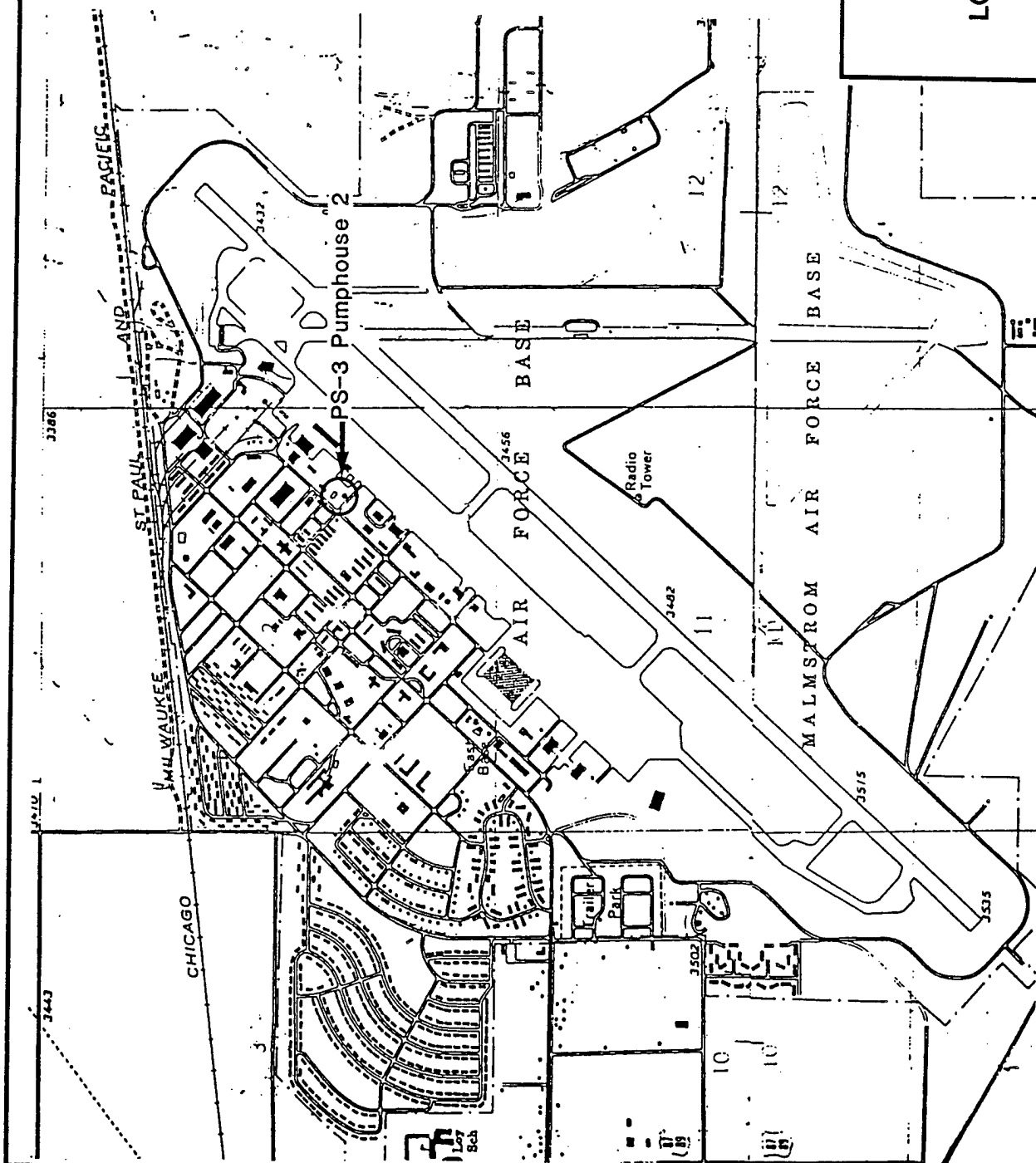
FIGURE 2.1

REGIONAL LOCATION OF MALMSTROM AFB

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

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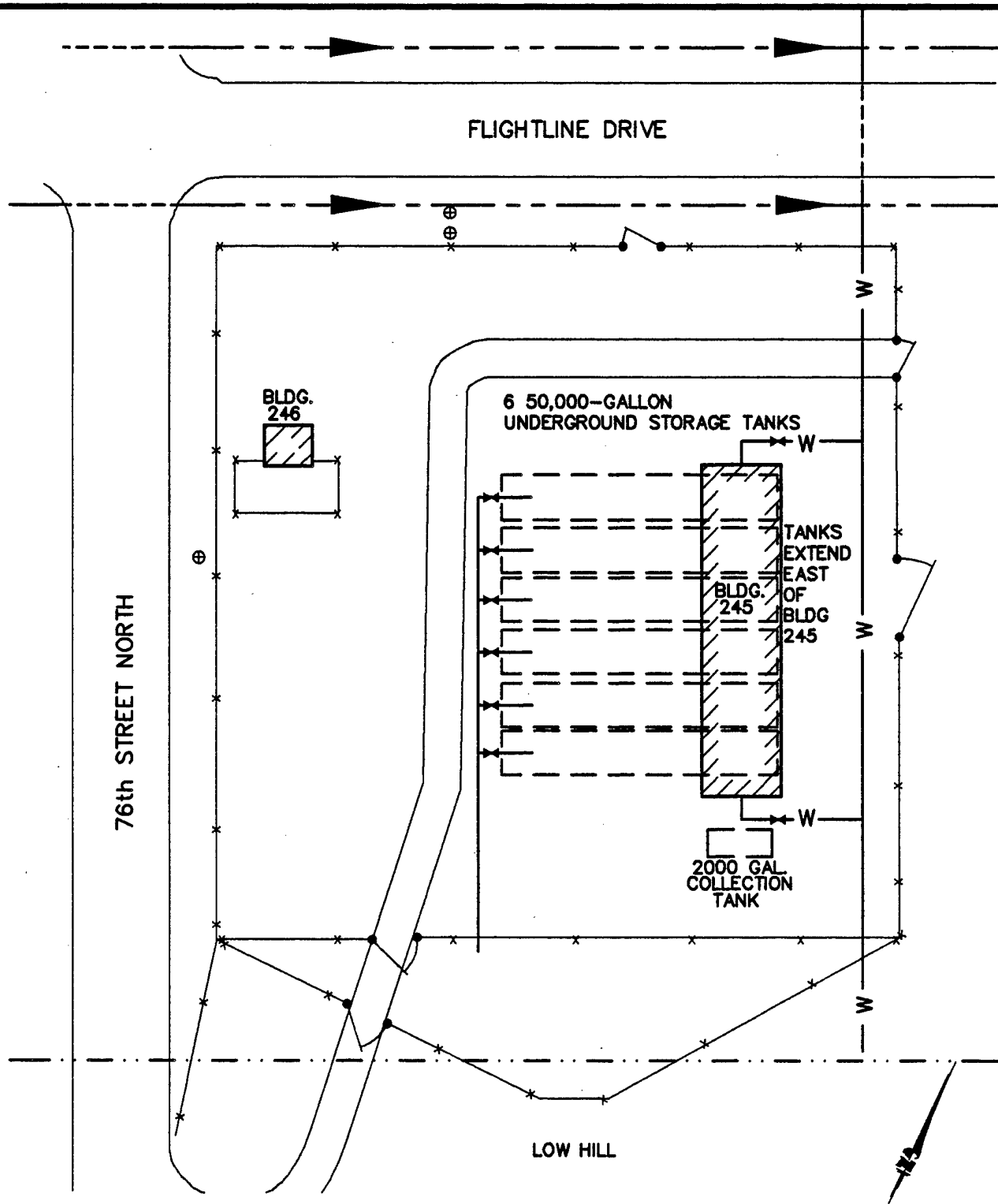
FIGURE 2.2

LOCATION OF PUMPHOUSE #2


EE/CA Work Plan
 Risk-Based approach to Remediation
 Pumphouse #2, Malmstrom AFB, Montana

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LEGEND

- W — WATER LINE
- - - - - 10" STORM DRAIN
- — — — — DRAINAGE DITCH
- * — * — * CHAIN LINK FENCE
- ⊕ POWER POLE
-  BUILDING

NOT TO SCALE

FIGURE 2.3

SITE LAYOUT

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

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The source of this diesel fuel was thought to be USTs at Pumphouse #2. It is possible that there are multiple sources of contamination at the site. Diesel fuel may be present inside the fenced area; however, the presence of high concentrations of volatiles across Flightline Drive indicates that jet fuel (JP-4) may be a contaminant at Pumphouse #2.

Benzene, ethylbenzene, total xylenes, and naphthalene have been detected in soil and ground water at Pumphouse #2. Of these contaminants, ethylbenzene was detected most frequently. Benzene and ethylbenzene were the only volatile organic compounds (VOCs) detected at concentrations above their federal maximum contaminant levels (MCLs) of 5 parts per billion (ppb) for benzene and 700 ppb for ethylbenzene. Benzene exceeded its MCL at two wells MW-15 and MW-18 at concentrations of 37 and 890 ppb, respectively. Ethylbenzene exceeded its MCL at well MW-18 at a concentration of 870 ppb. To date, no free product has been found in the three ground water monitoring wells at Pumphouse #2. Further details on the physical characteristics of Pumphouse #2 and the probable nature and extent of subsurface fuel hydrocarbon contamination are presented in subsequent sections of this work plan.

2.2 PHYSICAL SETTING

Data from previous site characterization efforts were reviewed, and relevant portions of these data are summarized in the following sections.

2.2.1 Site Topography and Surface Hydrology

Figure 2.2 shows the location of Pumphouse 2 with respect to the entire Malmstrom AFB and the surrounding environs. The site has relatively flat topography which slopes gently to the northeast. No abrupt elevation changes occur within the area except for a low hill running along the southeastern edge of the site and deep drainage ditches running along either side of Flightline Drive to the northwest of the site (refer to Figure 2.3).

No permanent surface water bodies exist on Malmstrom AFB (SAIC, 1991). Several ephemeral ditches and coulees run across the base. The only ephemeral surface water bodies located in the vicinity of Pumphouse #2 are the deep drainage ditches located immediately to the northwest of the site. The ditches along Flightline Drive convey water only during heavy precipitation events and spring runoff. All storm water on base is directed into either ditches or coulees that ultimately drain into the Missouri River located approximately 1 to 2 miles north of the northern boundary of the base (Figure 2.1) (SAIC, 1991).

Surface elevations range from 3,446 feet above mean sea level (MSL) on the crest of the hill southwest of Pumphouse #2, to 3,434 feet MSL in the bottom of a drainage ditch along Flightline Drive. Surface drainage is primarily toward the asphalt parking lot to the northeast of the site. This parking lot in turn discharges into the drainage ditch along Flightline Drive.

Surface features at the site include concrete driveways, chain-link fencing, tank and electrical vaults, fill stands, transformers, a pumphouse (Building 245), and an electrical control building (Building 246). All of these features will be removed during the June 1995 demolition of the site.

The Soil Conservation Service (SCS) has identified one primary soil association at Pumphouse #2, the sandy loam and sandy-clay loam of the No. 53 Dooley series. The permeability of these surficial soils can range from 0.6 to 6.0 inches per hour (SAIC, 1991).

2.2.2 Site Geology and Hydrogeology

The geology of Malmstrom AFB consists of a thick layer of glacial till and glaciolacustrine deposits overlying the Kootenai Formation. Pumphouse #2 is located in the northwestern portion of the base where deposits of aeolian sand are common. Depth to the Kootenai Formation in this area of the base is estimated to be about 200 feet (HDR, 1994). No borings have been advanced past 21 feet below ground surface (bgs) as part of any previous investigations at Pumphouse #2.

Figure 2.4 depicts the location of the hydrogeologic cross sections developed under previous site investigation efforts used to characterize the stratigraphy of Pumphouse #2. Figures 2.5, 2.6, and 2.7 show two north-south and one east-west hydrogeologic cross section for Pumphouse #2. At Pumphouse #2, the geology consists of glacial till overlain by aeolian sand deposits with areas of sand and gravel fill material. The till in the area consists of a lean to fat clay containing isolated lenses of sand and gravel. Depth of the aeolian deposits averages 4 to 6 feet across the site (HDR, 1994).

The shallowest water-bearing zone underlying Pumphouse #2 is an unconfined, perched aquifer. Ground water is found in the permeable aeolian deposits that overlie the impermeable glacial till at the site. Depth to ground water at the site is very shallow, ranging from 2.75 to 4.42 feet bgs during measurements taken by ES on 19 April 1994. ✓

Figure 2.8 is a map of the approximate ground water surface at Pumphouse #2. Ground water flow is generally northeastward following surface topography as it parallels the runway. Utility and pipeline conduits may provide preferential pathways for ground water at the site (HDR, 1994). No slug tests or other hydrogeologic testing has been performed at the site. To determine hydraulic conductivity and an estimate of ground water velocity, four slug tests will be performed at the site as part of this demonstration project. This requirement for the additional field testing is described further in Section 4 of this work plan.

2.3 NATURE AND EXTENT OF CONTAMINATION

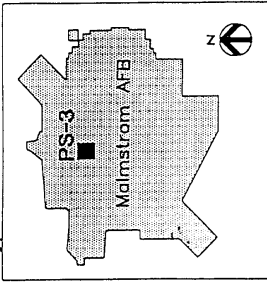
The following sections summarize existing analytical data on the nature and extent of contamination at or migrating from Pumphouse #2. Data from previous IRP and RFI sampling events and several soil gas surveys have been reviewed to estimate the probable nature and extent of contamination at the site.

2.3.1 Soil Gas Data

Three soil gas surveys have been performed at Pumphouse #2. Two large surveys were performed during the IRP Phase II Stage 2 investigation (SAIC, 1991) and during the RFI (HDR, 1994). A localized survey was performed during the AFCEE bioventing pilot test program (ES, 1993).

The survey performed by SAIC consisted of 83 sampling points spread along both sides of 76th Street and Flightline Drive (formerly Avenue "I" and First Street, respectively). The locations of the survey points are shown in Figure 2.9. Samples were analyzed for total volatile

Keyplan



Legend

- SB-01 Soil Boring Location
- SB-02 Soil Boring Completed as a Groundwater Monitoring Well (MW-02)
- SS-01 Surface Soil Sampling Location

Notes:

1. The approximate locations of the underground piping associated with the hydrant refueling system (PS-3) and fuel supply and return lines (PS-4) are based on drawings provided by MAFB while in the process of obtaining digging permits.

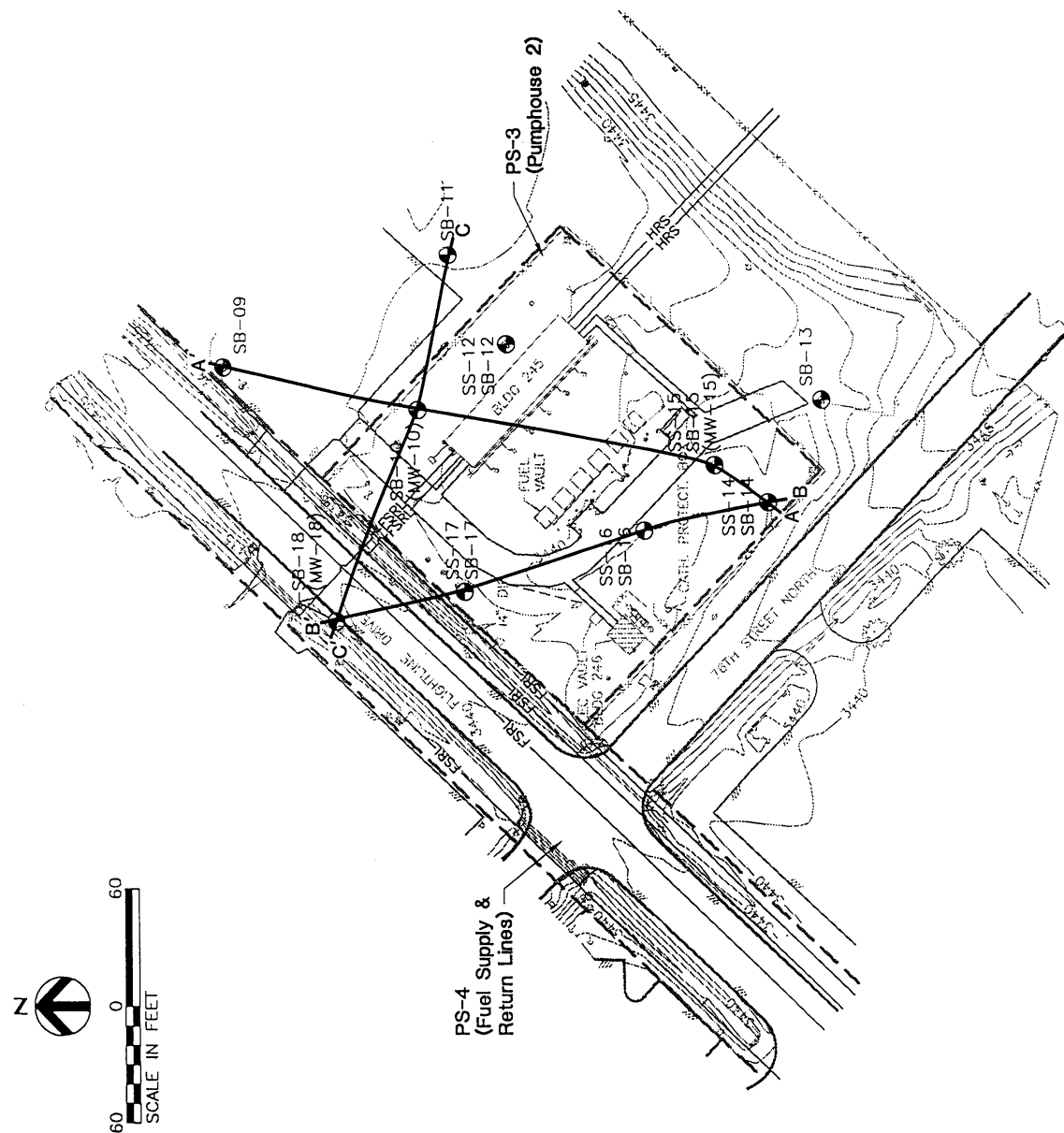
FIGURE 2.4

LOCATIONS OF HYDROGEOLOGIC CROSS SECTIONS

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

ENGINEERING-SCIENCE, INC.

Denver, Colorado



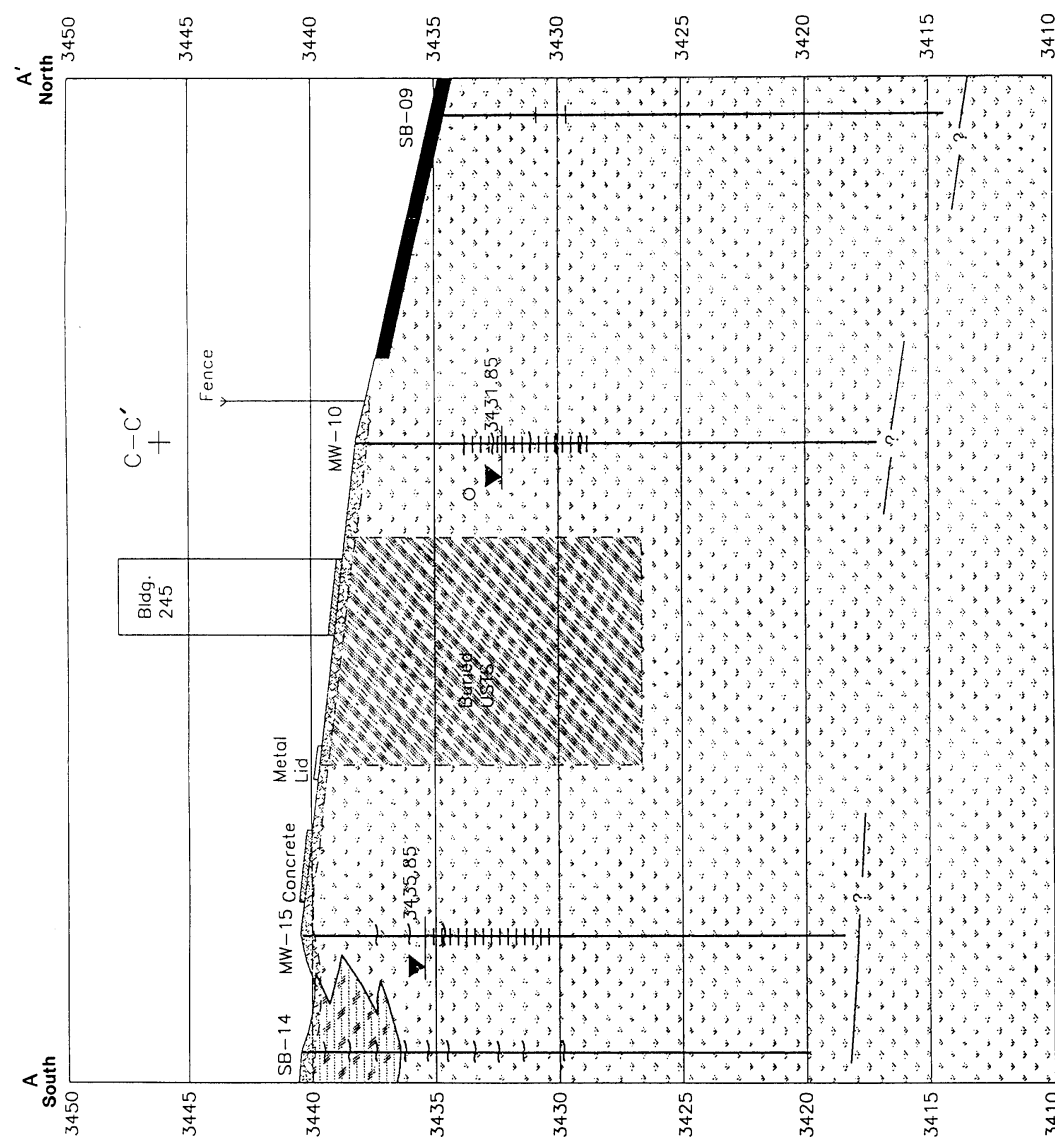


FIGURE 2.5

**NORTH-SOUTH HYDROGEOLOGIC
CROSS SECTION A-A'**

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

ENGINEERING-SCIENCE, INC.

Source: HDR, 1994.

Scale: Horiz. 1"=40'
Vert. 1"=5'

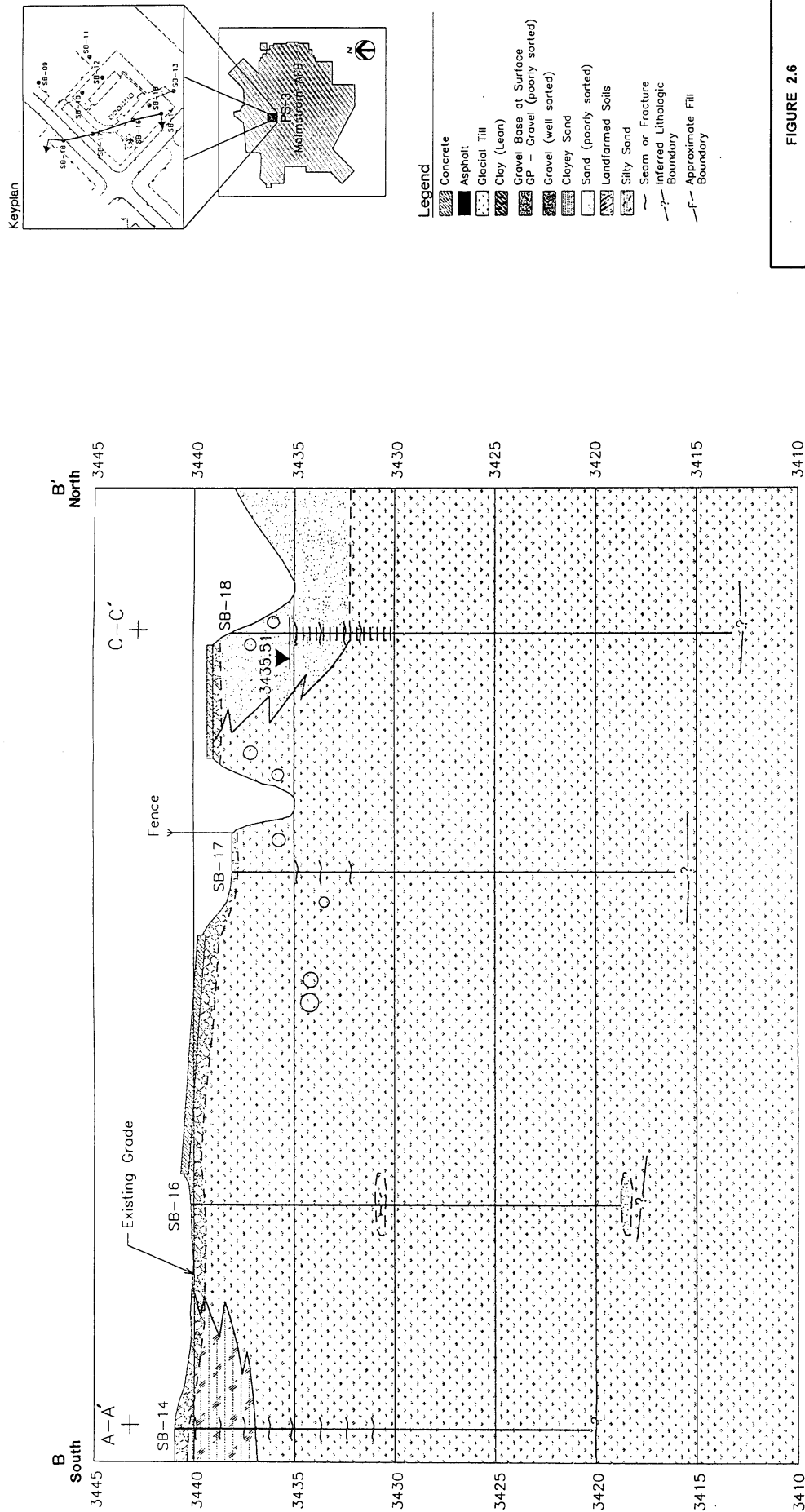


FIGURE 2.6
NORTH-SOUTH HYDROGEOLOGIC
CROSS SECTION B-B'

EE/CA Work Plan
 Risk-Based Approach to Remediation
 Pumphouse #2, Malmstrom AFB, Montana
ENGINEERING-SCIENCE, INC.
 Denver, Colorado

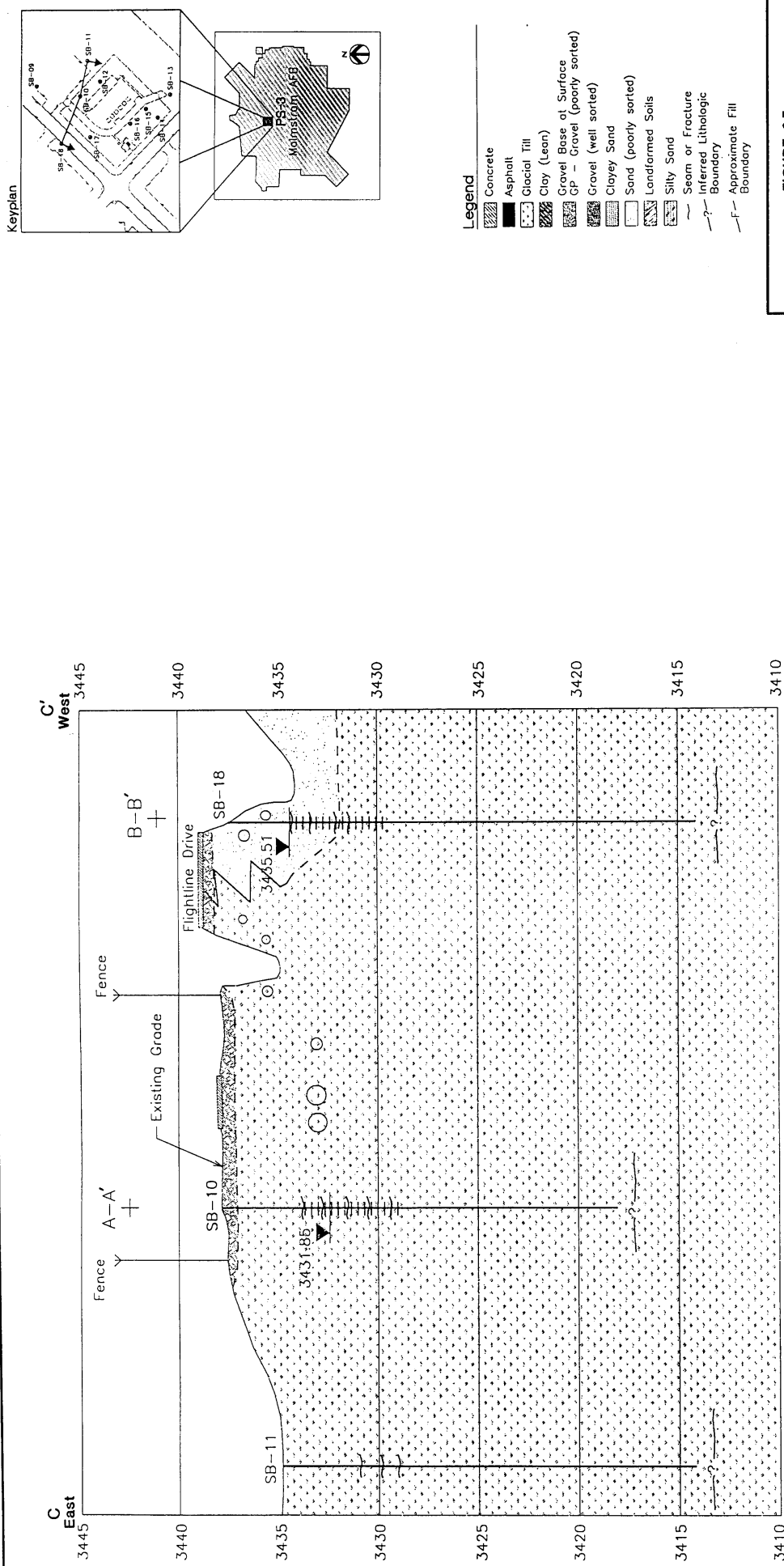


FIGURE 2.7

EAST-WEST HYDROGEOLOGIC CROSS SECTION C-C'

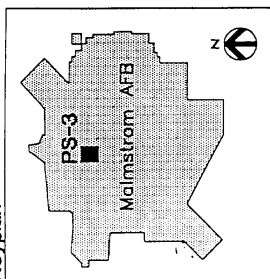
EE/CA Work Plan
 Risk-Based Approach to Remediation
 Pumphouse #2, Mainstrom AFB, Montana

ENGINEERING-SCIENCE, INC.
 Denver, Colorado



60 0 60
SCALE IN FEET

Keyplan



Legend

- SB-01 Soil Boring Location
- SB-02 Soil Boring Completed as a Groundwater Monitoring Well (MW-02)
- 3435.8-- Groundwater Contour

Notes:

1. The approximate locations of underground piping associated with the hydrant refueling system (PS-3) and fuel supply and return lines (PS-4) are based on drawings provided by MAFB while in the process of obtaining digging permits.

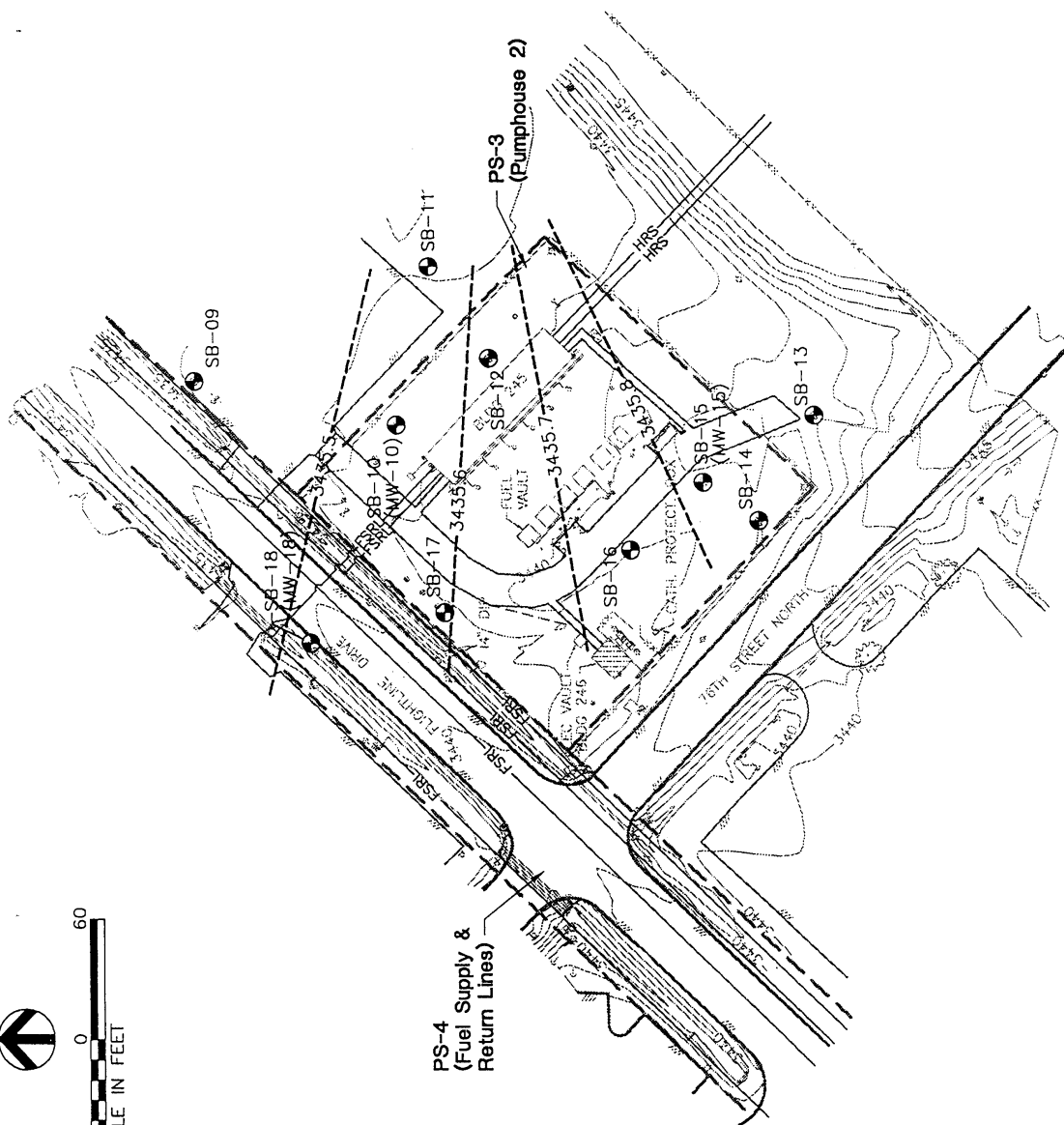


FIGURE 2.8

GROUND WATER SURFACE MAP

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana
ENGINEERING-SCIENCE, INC.
Denver, Colorado

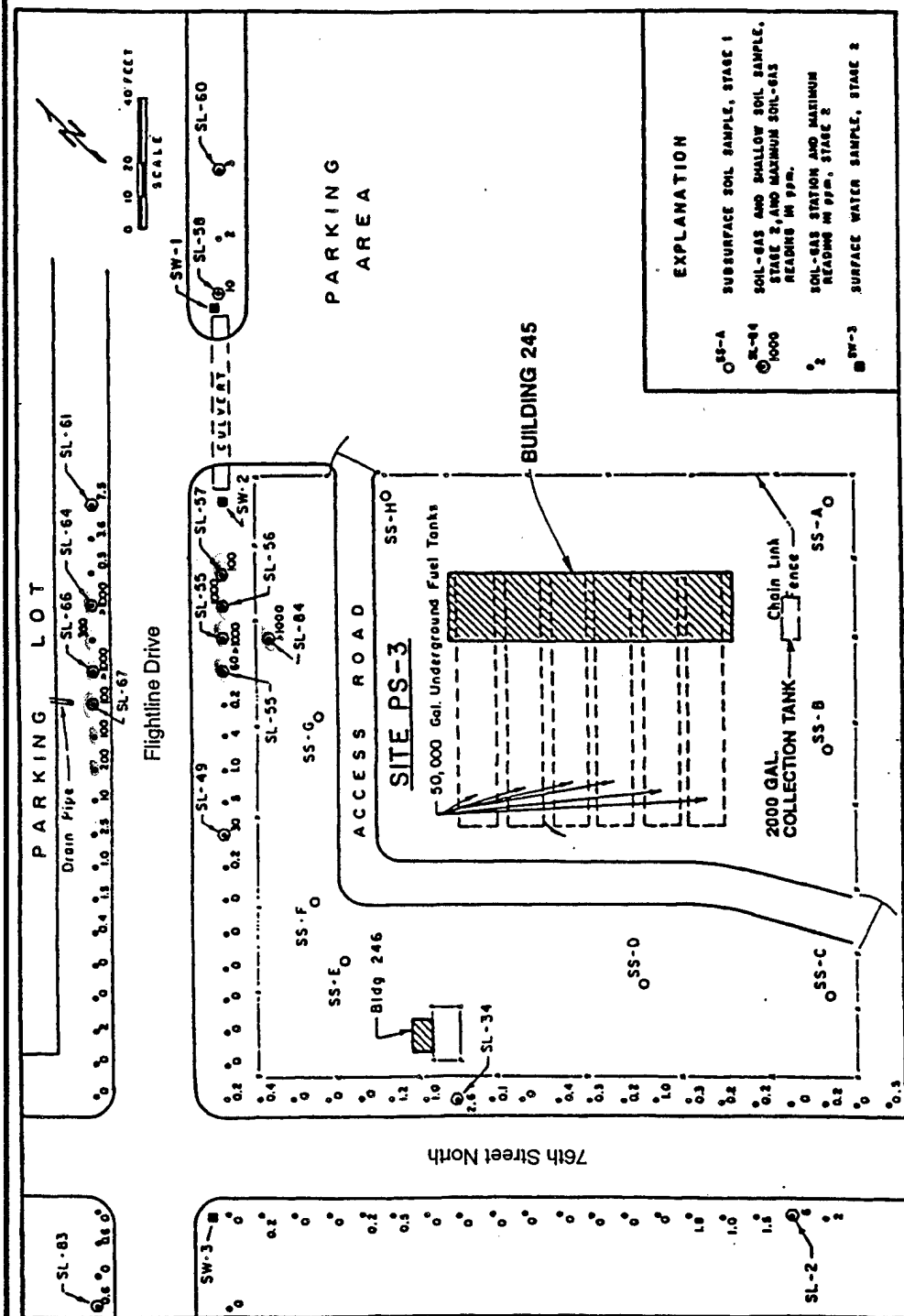


FIGURE 2.9

RFI PHASE II SOIL GAS SAMPLING LOCATIONS AND CONCENTRATIONS

**EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom Afb, Montana**

ENGINEERING-SCIENCE, INC.

Source: SAIC, 1991.

Denver, Colorado

hydrocarbon (TVH) only and were not analyzed for any of the BTEX compounds or other VOCs. Ten of the 83 points registered concentrations greater than 100 parts per million, volume per volume (ppmv) with 5 of the 10 showing greater than 1,000 ppmv of TVH. All of these elevated readings are grouped along Flightline Drive just to the northwest of Building 245 (refer to Figure 2.9). As shown in Figure 2.8, two pipelines run from Building 245 to fuel supply and return lines paralleling Flightline Drive. Both of these lines have been removed from service. The areas of elevated soil gas readings coincide with the intersections of these fuel lines, suggesting that they may be the primary source of contamination.

Following the SAIC soil gas survey, Tracer Research Corporation was subcontracted by HDR Engineering to perform an extensive soil gas survey inside and adjacent to the fenced area at Pumphouse #2. As shown in Figure 2.10, 76 sampling points were sampled during this field investigation. Again, samples were only analyzed for TVH. Eight sampling points showed concentrations greater than 100 ppmv. Four additional locations probes were pushed below the ground water surface. Ground water was pulled from these locations and sampled for total petroleum hydrocarbons (TPH). Four of these water samples had concentrations greater than 100 parts per million (ppm). One of the samples, taken in the immediate location of MW-18, had a concentration of 2,400 ppm. Areas of high soil gas contamination appear to be centered around the USTs and pumphouse and a smaller area north of Flightline Drive. Based on these soil gas results, soil borings were installed as part of the facility investigation. Sampling results for these borings are presented in Section 2.3.2 of this work plan.

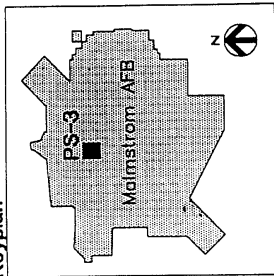
Soil gas samples were also collected in 1993 by ES during bioventing pilot testing. Samples were collected from a depth of 4 feet bgs in the area of the pilot test, located along the fence at the northwestern edge of the site adjacent to SB-17 (refer to Figure 2.4). Contaminated soil gas in this area had high concentrations of TVH, but low concentrations of the benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds. Toluene was not detected in any of the samples, but benzene was detected in one of the three samples collected. Laboratory analysis of TVH concentrations in soil gas samples ranged between 5,400 and 14,000 ppmv. Maximum benzene, ethylbenzene, and total xylene concentrations measured during the 1993 sampling event were 19, 13, and 15 ppmv, respectively.

The soil gas samples taken by ES had depleted oxygen concentrations ranging from 0.5 to 1.7 percent, and high carbon dioxide concentrations, suggesting that significant biological fuel degradation may be occurring in fuel-contaminated soils at the site (ES, 1993). However, because these 1993 soil gas samples are the only ones that have been analyzed for BTEX, additional soil gas samples are needed to better assess the potential risks associated with soil gas emanating from contaminated soil. Locations for these additional samples have been determined based on TVH concentration data from previous investigations. Section 4 of this work plan describes these additional requirements.

2.3.2 Soil Data

Soil data have been collected during discrete sampling events conducted under the various IRP characterization efforts (Battelle, 1988; SAIC, 1991), the RFI (HDR, 1994), and the bioventing demonstration project (ES, 1993). Investigations have included 21 soil borings as well as 15 surface soil samples.

Keyplan



Legend

- SB-01 Soil Boring Location (HDR, RFI)
- SB-02 (MW-02) Soil Boring Completed as a Groundwater Monitoring Well (HDR, RFI)

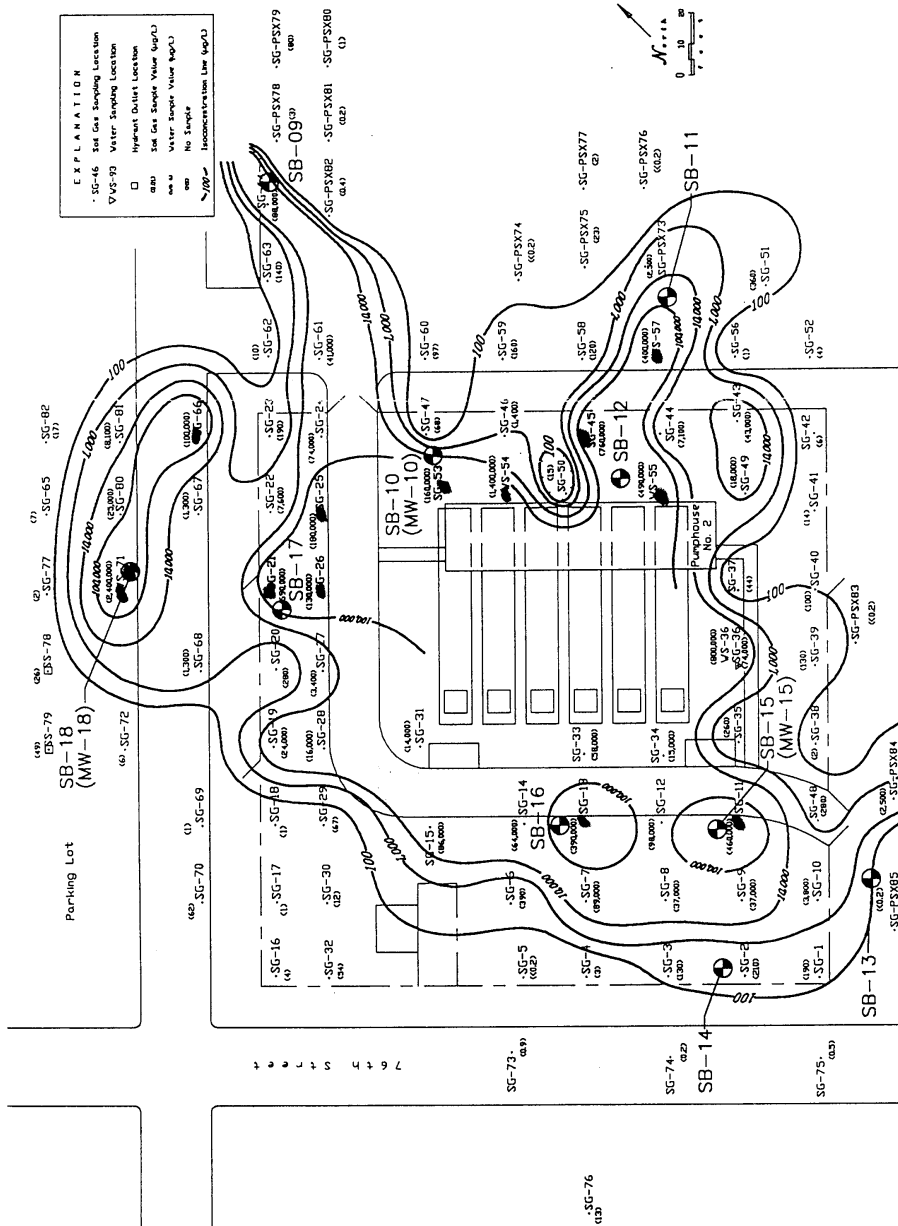
Notes:

1. Isoleths represent total volatile hydrocarbons, C4-C9.
2. Sampling locations are identified as either soil gas, soil or groundwater sampling locations. Soil gas and groundwater sample concentrations are presented in ug/L. Soil sample concentrations are presented in ug/kg.

FIGURE 2.10

RFI SOIL GAS SAMPLING LOCATIONS AND CONCENTRATIONS

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana
ENGINEERING-SCIENCE, INC.
Denver, Colorado



EXPLANATION	
●	Soil Gas Sampling Location
○	Water Sampling Location
□	Hydrant Outlet Location
○	Soil Gas Sample Value (ug/L)
○	Water Sample Value (ug/L)
○	No Sample
○	Isocentration Line (ug/L)

During the IRP Phase II, Stage 1 investigation (Battelle, 1988), eight soil borings were advanced to 1 to 4 feet bgs. Eight samples were collected for analytical data on total recoverable petroleum hydrocarbons (TRPH), VOCs, and lead. As shown in Figure 2.11, the borings (SS-A through SS-H) were spaced around the perimeter of the site. The sampling results shown on Table 2.1 indicate a few isolated areas of contamination around the perimeter of the site. The highest concentrations of TRPH and BTEX were found at boring SS-G. This boring was in the same area as several elevated soil gas readings. This is further evidence that the two fuel pipelines running out of Building 245 may be the primary source of subsurface contamination in this area. ✓

Fifteen surface (<1 foot bgs) soil samples were collected during the second stage of the IRP Phase II investigation. All of these samples were taken outside of the fenced area of Pumphouse #2 and were analyzed for TRPH, VOCs, and lead (Figure 2.11). Results of this sampling effort are shown on Table 2.2. Eight of the TRPH concentrations measured were above 100 ppm, and four locations had measurable quantities of ethylbenzene and xylene. The four locations at which BTEX compounds were found are located on either side of Flightline Drive in the vicinity of the pipelines that are suspected to be a source of contamination (HDR, 1994).

During bioventing pilot-scale testing at Pumphouse #2, three subsurface soil samples were collected. Depths of the samples ranged from 2 to 5.5 feet bgs. Laboratory results for TRPH and BTEX indicated low levels of contamination. TRPH concentrations ranged from 150 to 300 ppm, and BTEX concentrations ranged from 5.51 to 7 ppm (ES, 1993).

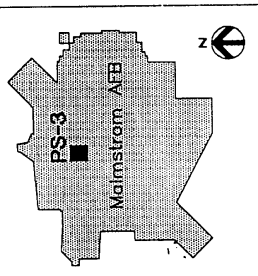
In July and August of 1993, a more intensive soil sampling event was performed for the RFI. Five surface soil samples were collected, and 40 subsurface samples were collected and analyzed from 10 borings. Analytical samples were collected from 5, 10, 15, and 20 feet bgs in the borings. Three of the borings were completed as ground water monitoring wells (Figure 2.12). Boring locations were based on the results of the soil gas survey performed by Tracer Research Company in 1992 (HDR, 1994). Table 2.3 contains the surface soil sampling results and results from samples collected from 5 feet bgs, the most contaminated interval at the site.

Surface sample data indicate two locations had concentrations of TRPH greater than 100 ppm. Samples SS-17-001 and SS-16-001 had concentrations of 378 and 3,310 ppm, respectively. VOCs were found in samples SS-12-001, SS-16-001, and SS-17-001. No BTEX compounds were reported, and the measured concentrations in shallow soil of the remaining organic compounds, mainly naphthalene, were equal to or less than 10 ppm (HDR, 1994).

Four of the samples collected from 5 feet bgs had concentrations of TRPH greater than 100 ppm. Samples from borings SB-11, SB-15, SB-17, and SB-18 had concentrations of 211, 429, 168, and 7,980 ppm respectively. BTEX compounds were found in all but two of the samples with ethylbenzene and xylenes being the most prevalent. Two samples had ethylbenzene and xylenes concentrations greater than 10 ppm. Samples SB-15-005 and SB-18-005 had ethylbenzene concentrations of 17 and 83 ppm, respectively. Samples SB-15-005 and SB-18-005 also showed concentrations of xylenes of 67 and 300 ppm, respectively. Benzene was found in one sample, SB-12-005, at a concentration of 23 ppb (HDR, 1994).

Samples collected from 10 feet bgs were generally not contaminated. TRPH was reported in one sample, SB-13-010, at a concentration of 66.4 ppm. Ethylbenzene was reported in two

Keyplan



Legend

- o SL-84 Shallow Soil Sample Installation Restoration Program, July 1991
- o SW-3 Surface Water Sample Installation Restoration Program, July 1991
- SS-A Subsurface Soil Sample Installation Restoration Program, Phase II, Nov. 1988

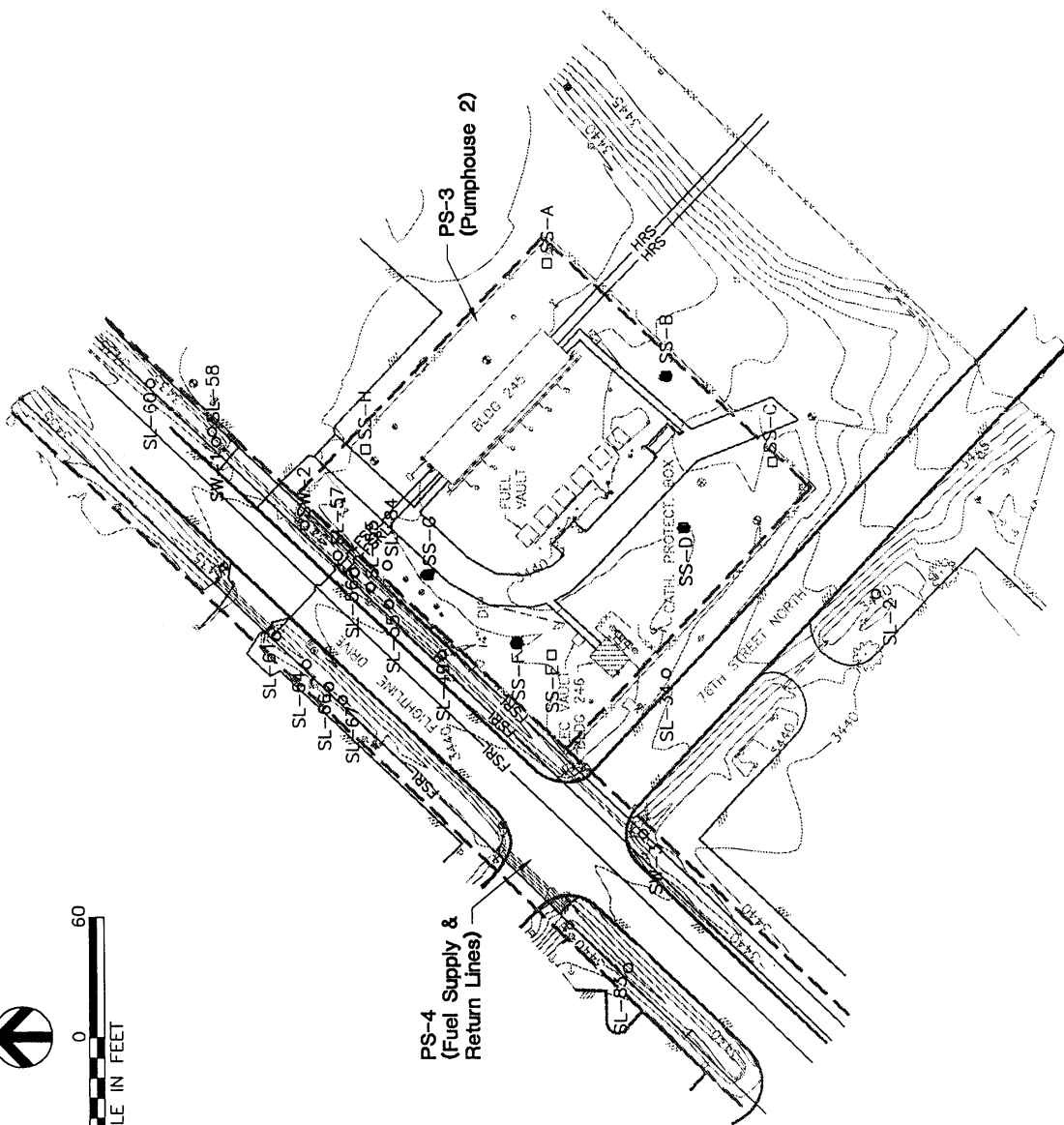
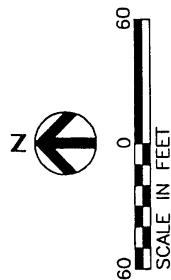


FIGURE 2.11

IRP PHASE II SOIL SAMPLING LOCATIONS

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

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TABLE 2.1

ANALYTICAL RESULTS FOR SUBSURFACE SOIL SAMPLES
 IRP PHASE II, STAGE 1 INVESTIGATION
 EE/CA WORK PLAN
 RISK-BASED APPROACH TO REMEDIATION
 PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Sample Location	SS-A	SS-B	SS-C	SS-D	SS-E	SS-F	SS-G	SS-H
Sample Depth (feet bgs)	4	3	4	4	1	4	4	4
Parameter:								
Moisture (%)	23.6	19.2	16.8	29.9	18.0	24.9	20.0	21.5
Total Recoverable Petroleum								
Hydrocarbons (ppm)	ND ^{a/}	166	ND	875	ND	374	2390	ND
Lead (ppm)	12.3	7.6	9.6	14.2	12.6	12.0	ND	11.1
Toluene (ppm)	ND	1.7	6.9	ND	ND	ND	ND	ND
Ethylbenzene (ppm)	ND	3.7	4	ND	ND	ND	36.3	ND
Total Xylenes (ppm)	ND	22.8	16.6	ND	ND	ND	242.6	ND

^{a/} ND = Not detected.

Source: Battelle, 1988.

TABLE 2.2

ANALYTICAL RESULTS FOR SHALLOW SOIL SAMPLES
IRP PHASE II, STAGE 2 INVESTIGATION
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

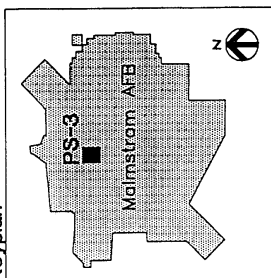
Sample Location	SL-83	SL-34	SL-2	SL-60	SL-61	SL-58	SL-49	SL-54
Parameter:								
Moisture (%)	18	8	13	16	11	15	12	19
Total Recoverable Petroleum								
Hydrocarbons (ppm)	44	10,100	160	29	120	31	160	190
Lead (ppm)	38	9	60	70	190	31	10	20
Toluene (ppm)	ND ^{a/}	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene (ppm)	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes (ppm)	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride (ppm)	ND	ND	ND	ND	ND	ND	ND	ND

Sample Location	SL-57	SL-64	SL-67	SL-66	SL-56	SL-84	SL-55
Parameter:							
Moisture (%)	26	21	17	21	17	21	21
Total Recoverable Petroleum							
Hydrocarbons (ppm)	72	14	280	400	100	ND	1000
Lead (ppm)	ND	42	ND	30	10	20	ND
Toluene (ppm)	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene (ppm)	ND	ND	ND	4	ND	20	75
Total Xylenes (ppm)	ND	65	ND	107	ND	68	270
Methylene Chloride (ppm)	ND	ND	ND	ND	ND	ND	ND

^{a/} ND = Not detected.

Source: SAIC, 1991.

Keyplan



Legend

- ⊕ SB-01 Soil Boring Location
- ⊕ SB-02 Soil Boring Completed as a Groundwater Monitoring Well (MW-02)
- ⊕ SS-01 Surface Soil Sampling Location

Notes:

1. The approximate locations of underground piping associated with the hydrant refueling system (PS-3) and fuel supply and return lines (PS-4) are based on drawings provided by MAFB while in the process of obtaining digging permits.

FIGURE 2.12

RFI SOIL SAMPLING LOCATIONS

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

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Denver, Colorado

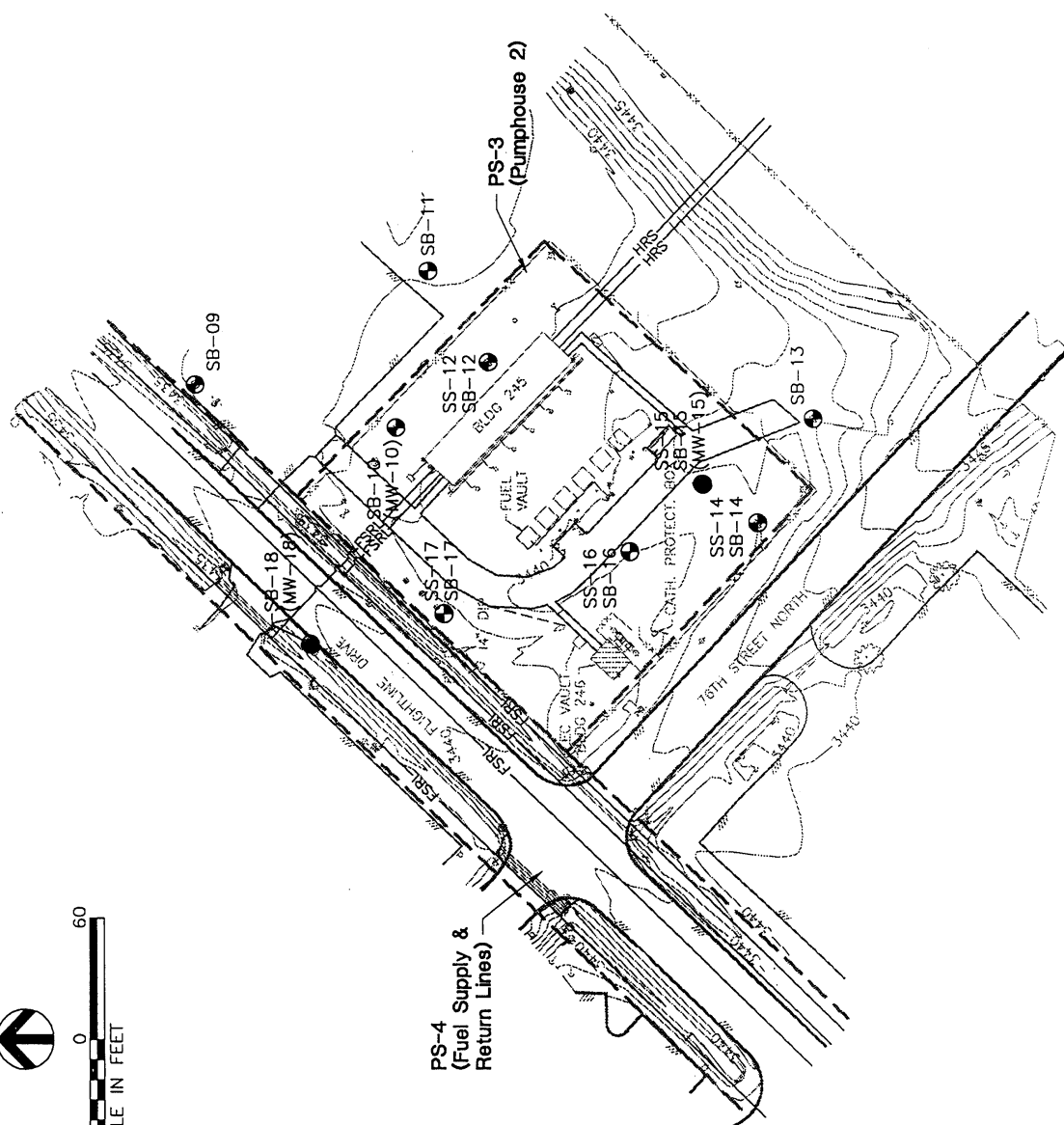


TABLE 2.3

ANALYTICAL RESULTS FOR SURFACE SOIL AND SUBSURFACE SOIL SAMPLES
 RCRA FACILITY INVESTIGATION
 EE/CA WORK PLAN
 RISK-BASED APPROACH TO REMEDIATION
 PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Sample Location	SS-12	SS-14	SS-15	SS-16	SS-17	SB-9	SB-10	SB-11
Sample Depth (feet bgs)	1	1	1	1	1	5	5	5
Parameter:								
Moisture (%)	11.6	11.9	12.8	11.5	16	20	25.9	20.3
Total Recoverable Petroleum								
Hydrocarbons (ppm)	33	ND ^{a/}	51.2	3,310	378	ND	ND	211
Lead (ppm)	18.4	11.3	12	8.2	12.4	10.9	9.2	10.2
Ethylbenzene (ppb)	ND	ND	ND	ND	ND	810	ND	7500
Total xylenes (ppb)	ND	ND	ND	ND	ND	510	ND	ND
Fluoranthene (ppb)	1,400	ND	ND	6,200	1,700	ND	ND	ND
Pyrene (ppb)	1,400	ND	ND	4,600	ND	ND	ND	ND
Phenanthrene (ppb)	ND	ND	ND	7,400	ND	1,300	ND	ND
Benzo(a)anthracene (ppb)	ND	ND	ND	ND	ND	460	ND	ND
2-Methylnaphthalene (ppb)	ND	ND	ND	10,000	3,600	1,400	ND	1,700
Napthalene (ppb)	ND	ND	ND	6,800	2,200	1,300	ND	930

TABLE 2.3 (continued)

ANALYTICAL RESULTS FOR SURFACE SOIL AND SUBSURFACE SOIL SAMPLES
RCRA FACILITY INVESTIGATION
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Sample Location	SB-12	SB-13	SB-14	SB-15	SB-16	SB-17	SB-18
Sample Depth (feet bgs)	5	5	5	5	5	5	5
Parameter:							
Moisture (%)	17.5	22	22.6	22	22.3	22.8	17
Total Recoverable Petroleum							
Hydrocarbons (ppm)	ND	72.9	ND	429	ND	168	7,980
Lead (ppm)	8.4	10.3	9	8.4	7.4	9	6.5
Benzene (ppb)	23	ND	ND	ND	ND	ND	ND
Ethylbenzene (ppb)	100	ND	900	17,000	78	5,600	83,000
Total xylenes (ppb)	350	ND	1,500	67,000	ND	710	300,000
Fluoranthene (ppb)	ND	ND	ND	4,900	ND	ND	ND
Pyrene (ppb)	ND	ND	ND	3,600	ND	ND	ND
Phenanthrene (ppb)	ND	ND	ND	5,100	ND	ND	ND
2-Methylnaphthalene (ppb)	ND	ND	2,000	5,700	ND	ND	17,000
Napthalene (ppb)	ND	ND	730	4,500	ND	ND	8,900

^{a/} ND = Not detected.

Source: HDR, 1994.

samples (SB-10-010 and SB-11-010), and xylenes were reported in one sample (SB-18-010). Detected concentrations for both compounds at these locations were below 1 ppm (HDR, 1994).

No samples collected from 15 or 20 feet bgs had detectable concentrations of TRPH. One sample from 15 feet bgs had BTEX concentrations. Sample SB-18-015 had an ethylbenzene concentration of 89 ppb and a total xylenes concentration of 250 ppb (HDR, 1994). No samples at 20 feet bgs had detectable concentrations of BTEX or any other VOC compounds.

Based on the soil contamination data collected to date, it appears that there has been a release of fuel in the subsurface and possibly multiple surface spills at Pumphouse #2. The vertical extent of contamination has been well determined by previous investigations. Further soil sampling during this field investigation will be used to delineate the horizontal extent of soil contamination at this site. Section 4 of this work plan describes additional soil sampling to be completed as part of this demonstration program.

2.3.3 Ground Water Data

The distribution of hydrocarbon contamination at Pumphouse #2 suggested by the soil gas surveys and soil data is further supported by ground water quality data from the 1993 RFI sampling event. Ground water data from three ground water monitoring wells located within and downgradient of the site (MW-10, MW-15, and MW-18) have been compiled in Table 2.4 to indicate the probable nature and extent of ground water contamination directly attributable to Pumphouse #2. Several VOCs and semivolatile organic compounds (SVOCs) were detected in the ground water at Pumphouse #2 during this sampling event, including benzene, ethylbenzene, total xylenes, phenol, carbazole, and naphthalene. It should be noted that carbazole was detected only in a field duplicate from MW-18. It was not detected in the other sample from the well. No chlorinated solvents were detected. Although three of the BTEX compounds (benzene, ethylbenzene and total xylenes) were detected in all three wells, only benzene and ethylbenzene were detected at concentrations above their federal MCLs of 5 ppb for benzene and 700 ppb for ethylbenzene. Benzene exceeded the MCL at wells MW-15 and MW-18, with concentrations of 37 and 890 ppb, respectively. Ethylbenzene exceeded the MCL at well MW-18 with a concentration of 870 ppb (HDR, 1994). To date, no free product has been found in the three ground water monitoring wells at Pumphouse #2. Figure 2.13 depicts the locations of the wells and the concentrations of the VOCs at the wells.

ES performed a preliminary survey of Pumphouse #2 in April 1994, during a respiration test being performed for the bioventing pilot test at the site. Water level and dissolved oxygen (DO) were monitored in the three wells at the site. Results from this activity are shown in Table 2.5. DO was depleted in all three wells, with readings ranging from 0.00 to 0.31 ppm.

Available electron acceptors for *in situ* biodegradation, such as DO and nitrate, may be present in the perched aquifer, but appear to be depleted in the Pumphouse #2 source area and plume. Additional sampling is required to better define the areal extent of the ground water plume with respect to contamination and electron acceptors, and the mass-transport characteristics of the aquifer within and downgradient of Site Pumphouse #2. Section 4 summarizes the additional hydrogeologic characterization activities that will be necessary to support the risk-based approach to remediation at Pumphouse #2.

TABLE 2.4

ANALYTICAL RESULTS FOR GROUND WATER
RCRA FACILITY INVESTIGATION
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

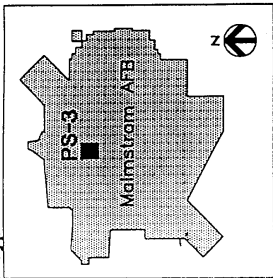
Sample Location	MW-10	MW-15	MW-18
Parameter:			
Benzene (ppb)	1.2	37	890
Ethylbenzene (ppb)	14	24	870
Total xylenes (ppb)	15	260	7,100
Napthalene (ppb)	ND ^{a/}	ND	150
Carbazole (ppb)	ND	ND	130 ^{b/}
Phenol (ppb)	ND	68	ND

^{a/} ND = Not detected.

^{b/} Duplicate sample.

Source: HDR, 1994.

Keyplan



Legend

MW-01 Groundwater Sampling Location

Sample Identification

Site Designation
 Groundwater Number
 PS-3-(MW01)

Abbreviation Identification

SVOCs Semi-Volatile Organic Compounds
 BTEX Benzene, Toluene, Ethylbenzene, & Xylenes

FIGURE 2.13

RFI GROUND WATER WELLS AND VOC CONCENTRATIONS

EE/CA Work Plan

Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

ENGINEERING-SCIENCE, INC.

Denver, Colorado

2-74

Notes:

1. Only compounds greater than their respective reporting limit are presented.
2. Samples were analyzed for BTEX, SVOCs, and dissolved metals.
3. The approximate locations of underground piping associated with the hydrant refueling system (PS-3) and fuel supply and return lines (PS-4) are based on drawings provided by MAFB while in the process of obtaining digging permits.

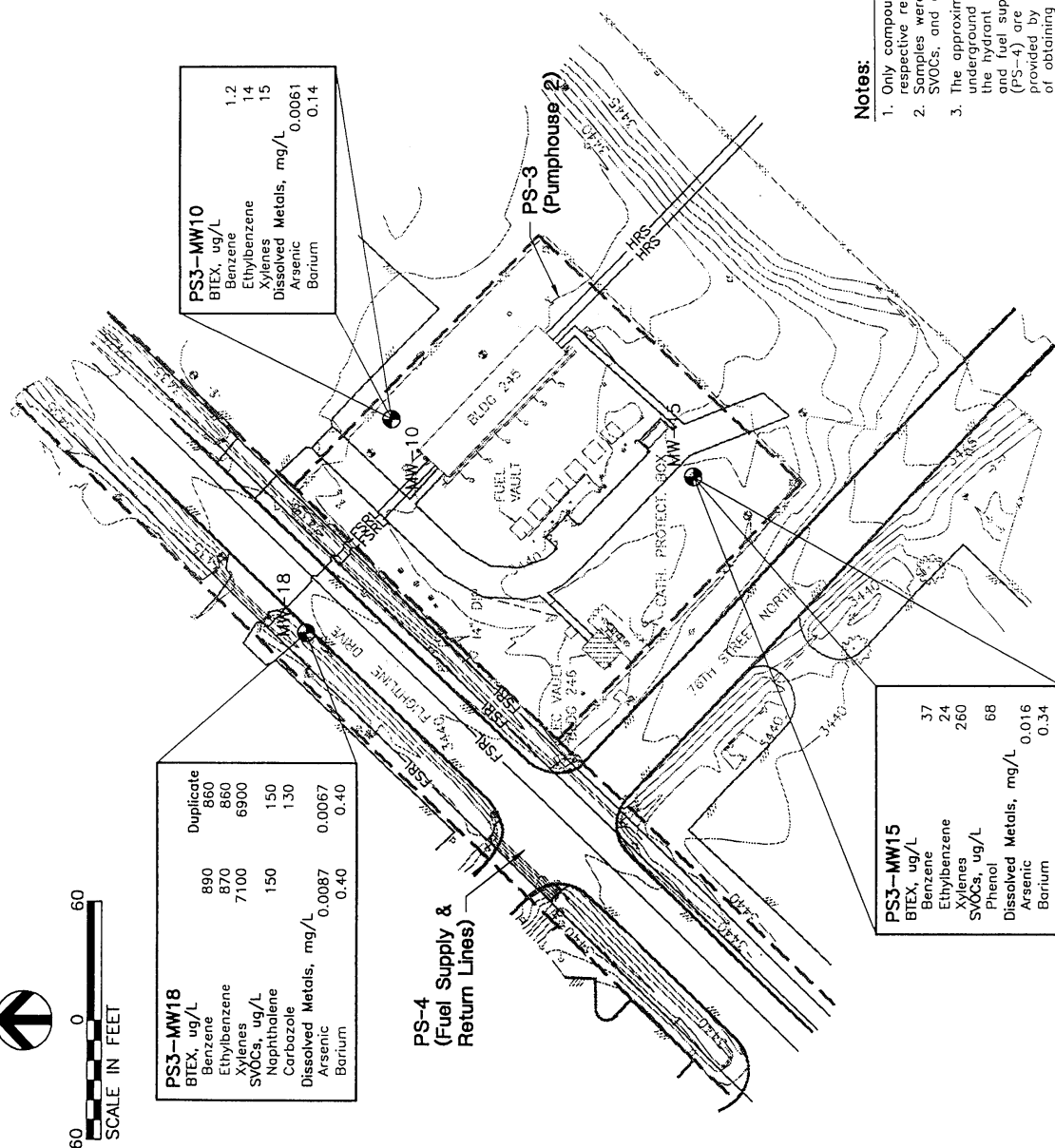


TABLE 2.5

**WATER LEVEL AND DISSOLVED OXYGEN CONCENTRATIONS MEASURED
DURING FIELD TESTING BY ENGINEERING-SCIENCE, INC., APRIL 1994
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA**

Well	Water Level (feet below top of casing)	Dissolved O ₂ at 1 Foot Below Water Surface (ppm)
MW-10	3.83	0.00
MW-15	4.42	0.04
MW-18	2.75	0.31

2.3.4 Surface Water Data

Three surface water samples were collected from the drainage immediately to the northwest of the site during the IRP investigation (SAIC, 1991). The samples were analyzed for TPH, VOCs, lead, and water quality constituents (common anions and TDS). No concentrations of TPH or VOCs were detected. Section 4 defines several additional characterization activities designed to provide sufficient data on the potential for surface water contamination due to seepage of shallow ground water at Pumphouse #2.

2.3.5 Frequency of Free Product

Free-phase fuel product has not been observed in any of the wells at Pumphouse #2. If free product appears in any of the wells installed as part of this field investigation, field personnel will attempt to collect a sample for chemical analysis. The sample will be analyzed for its total BTEX content to determine how the remaining free product is partitioning into the underlying ground water and contributing to the dissolved-phase BTEX plume at Pumphouse #2. Free product removal may be implemented as part of an engineered solution as needed.

SECTION 3

IDENTIFICATION OF SITE MODELS

It will be necessary to collect sufficient data to comparatively evaluate the long-term effectiveness of various remedial alternatives in eliminating or minimizing current or potential future risks to human health and the environment. Section 3.1 describes a conceptual site model for Pumphouse #2, which includes possible source and release mechanisms, governing fate and transport processes, potential exposure points and routes, and potential human and environmental receptors. Section 3.2 describes the Bioplume II model which will be used to quantitatively evaluate whether dissolved-phase ground water contamination can migrate to a receptor exposure point. Section 3.3 describes other quantitative contaminant fate and transport models that may be used to evaluate exposure potential from contamination in environmental media other than ground water.

3.1 CONCEPTUAL SITE MODEL

The purpose of developing a conceptual site model (CSM) is to evaluate existing information about the physical characteristics of the site, including potential contaminant sources, chemicals of concern, release mechanisms (e.g., leaching and volatilization), governing fate and transport processes (e.g., molecular diffusion, ground water migration), potential human and ecological receptors (e.g., current on-base workers, potential future on-base residents, current/future off-base residents, terrestrial vegetation and wildlife), exposure points (i.e., locations where receptors could come into contact with site-related contamination), and routes of exposure (e.g., inhalation, incidental ingestion, dermal contact), to identify the types of data necessary to quantify receptor exposure. The CSM will be used to define the nature of additional site characterization activities required at Pumphouse #2 to support identification, selection, and implementation of a final remedial alternative that minimizes contaminant migration and receptor exposure. The CSM constructed for Pumphouse #2 is shown schematically in Figure 3.1.

3.1.1 Definitions

The risk-based approach to remediation uses conservative quantitative models that account for the effects of fate and transport processes to estimate exposure point concentrations. The probable effectiveness of intrinsic remediation and other innovative source removal technologies such as bioventing to reduce exposure. The risk-based approach to remediation for Pumphouse #2 has been designed to satisfy these data objectives. It is appropriate at this point to define some of the key terms used in the risk-based approach to remediation. A *risk assessment* is the quantitative estimation of a hazard. A *baseline risk assessment* estimates the hazards that might exist if no remediation or institutional controls were applied at a site. A *conceptual site model*

SOURCES

AFFECTED MEDIUM

RELEASE MECHANISMS MIGRATION ROUTES

EXPOSURE ROUTES

POTENTIAL RECEPTORS

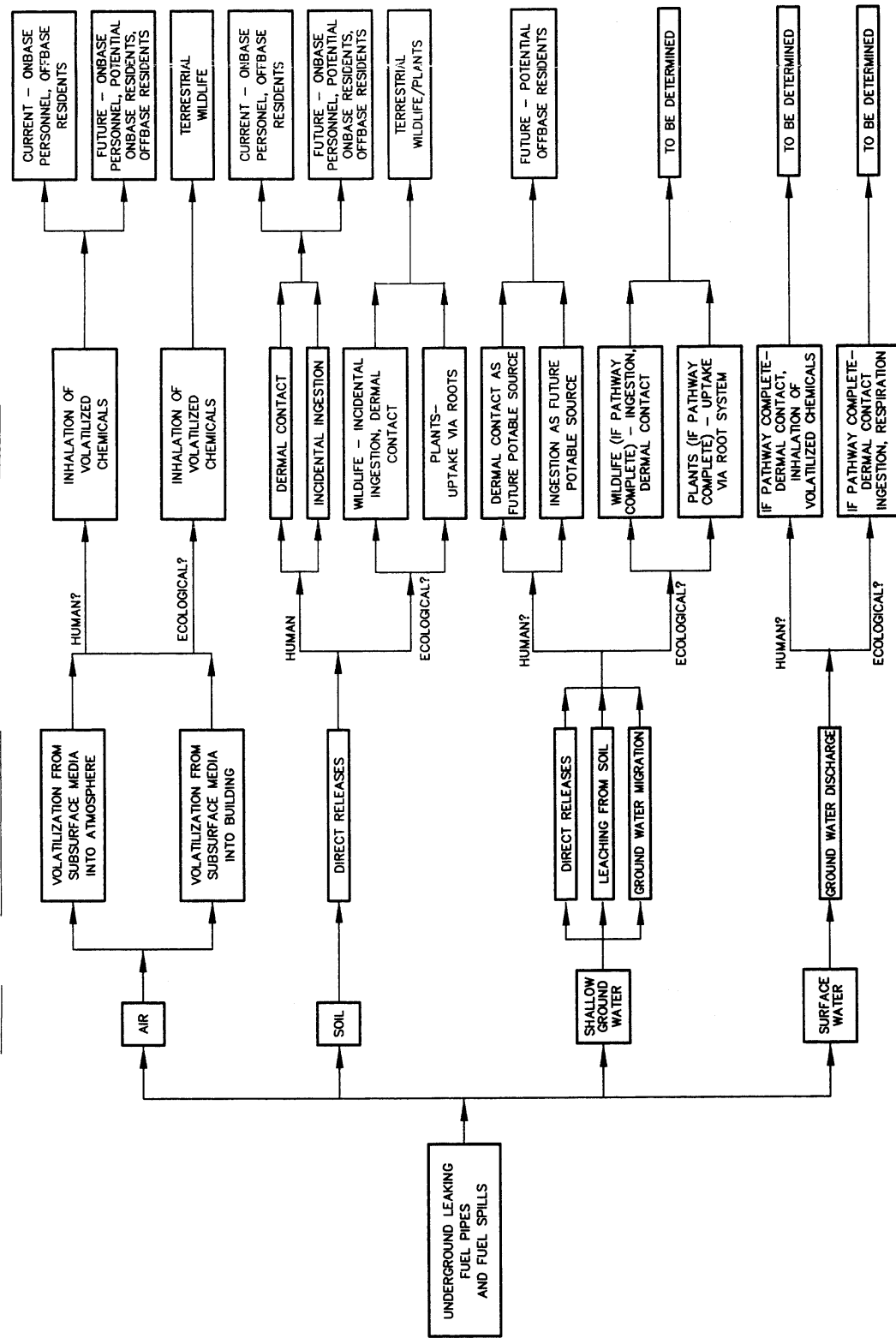


FIGURE 3.1

CONCEPTUAL SITE MODEL

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana
ENGINEERING-SCIENCE, INC.
Denver, Colorado

(CSM) qualitatively identifies how potential human and ecological receptors could come into contact with site-related contamination. A CSM is then used to assess data needs and guide data collection and analysis efforts. An *exposure assessment* involves estimating the type and magnitude of receptor exposures to contaminants of concern (COCs) that are present at or migrating from a site. COCs are chemicals that are potentially site-related and whose data are of sufficient quality for use in a quantitative risk assessment. A *risk assessment concentration* or *exposure-point concentration* is the highest concentration a potential receptor would reasonably be expected to contact. The risk-based approach to remediation uses conservative quantitative models that account for the effects of fate and transport processes to estimate exposure-point concentrations. The probable effectiveness of intrinsic remediation and other innovative source removal technologies such as bioventing to reduce exposure-point concentrations will be determined using conservative quantitative models.

Contaminant screening levels are conservative risk-based or promulgated criteria used to identify and screen out areas or environmental media that do not warrant further study. *Chemical-specific remediation goals* define the "acceptable" concentration of chemicals that can remain onsite following remediation and still meet remedial action objectives. Goals can either be risk-based or based on promulgated criteria. *Risk-based* These *cleanup remediation goals* are long-term target concentrations for environmental media based on target risk levels, toxicity information, and exposure equations rather than on promulgated cleanup standards. Remediation goals will be used to identify, select, and design an appropriate remedial alternative that will minimize or eliminate risks due to exposure to site-related contaminants. Remediation goals will be developed using site-specific land use assumptions, the procedures outlined in the EPA (1991a) Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-01B entitled *Human Health Evaluation Manual, Part B: Development of Risk-based Remediation Goals*. These remediation goals may be modified to address technical limitations, effectiveness, practicability, or other relevant considerations, including reasonable expected future exposure conditions at the site not already incorporated into the cleanup levels. These cleanup goals are then compared to the exposure-point concentrations developed using the quantitative fate and transport models to estimate the type and magnitude of remediation required to protect human health and the environment. More details on the proposed risk analysis methods are presented in Section 5 of this work plan.

3.1.2 Previous Risk Estimates

A quantitative baseline human health risk assessment has been completed for PS-3, which includes Pumphouse #2, at Malmstrom AFB (HDR, 1994). The baseline risk assessment included a screening assessment (to identify potential COCs), an exposure assessment, a toxicity assessment, and risk characterization. Conservative risk-based screening levels were developed as an evaluation criterion to supplement promulgated regulatory standards to aid in identifying chemicals and environmental media that could pose a health threat to potential receptors. Current land uses were identified as primarily industrial/military. No recreational or residential use of Pumphouse #2 or adjacent environs was identified. Residential development at Malmstrom is limited to the northwestern portion of the base. The baseline risk assessment assumed that the land use patterns would not change in the future as there are no current or foreseeable plans to expand housing into other portions of Malmstrom AFB. Residential use of the Pumphouse #2

area was deemed unlikely due to its proximity to the flightline and the industrial use of the area. Risk calculations using the residential land use assumption were only conducted for comparison and are included in the baseline risk assessment as a supplemental evaluation.

Comparison of detected constituents in soil at Pumphouse #2 (see Section 2) to the soil evaluation criterion developed during the initial screening step of the baseline risk assessment (HDR, 1994) indicate that no individual chemical constituent is present in the soils at the site at concentrations that may pose a risk to base or construction workers. Benzene, ethylbenzene, naphthalene, and possibly carbazole all were present in ground water at Pumphouse #2 at concentrations that exceeded their screening levels. The screening levels for benzene and ethylbenzene were the federal MCLs for these constituents; the screening levels for naphthalene and carbazole were based on toxicity information assuming residential use of ground water resources (HDR, 1994).

The potential human receptors included in the baseline risk assessment were limited to current and potential future base and construction workers. Ground water was not identified as an environmental medium which receptors could reasonably be expected to contact. Use of ground water from the perched shallow aquifer was not expected due to the availability of the public water supply system. The baseline risk assessment also found that beneficial use of this ground water resource was unlikely, as the aquifer is discontinuous and would not provide a viable source of drinking water (HDR, 1994). Therefore, the exposure routes included in the analysis were dermal contact with and incidental ingestion of surface soil for base and construction workers, dermal contact with and incidental ingestion of subsurface soil for construction workers, and inhalation of volatiles and fugitive dust. Potential future residents were considered only in a supplemental evaluation for comparison purposes.

Risk calculations indicated that both noncarcinogenic and carcinogenic risks to potential base and construction workers due to exposure to soil contamination at PS-3 were below levels of concern as identified by EPA (1989b) (i.e., a hazard index less than 1 and a carcinogenic risk level below 1×10^{-6}). All detected concentrations in soil at Pumphouse #2 were below the initial screening evaluation criterion developed during the baseline risk assessment process. Consequently, the baseline risk assessment concludes that no risk to potential receptors exists due to exposure to soil contamination at Pumphouse #2. Risk calculations for the residential exposure scenario indicate that the noncarcinogenic and carcinogenic risks associated with exposure to soil were not above levels of concern as identified by EPA. The estimated hazard index associated with soil exposure was 0.01. The carcinogenic risk associated with soil exposure was calculated to be 2.6×10^{-5} , which is within the EPA's acceptable carcinogenic risk range. The estimated hazard index associated with residential exposure to ground water was 0.5. The carcinogenic risk associated with residential exposure to ground water was 1.5×10^{-5} . Only those chemicals exceeding their respective screening levels were included in these evaluations.

A qualitative ecological risk assessment has also been completed for PS-3 (HDR, 1994). The ecological risk assessment paralleled the human health risk assessment in the steps taken to identify potential ecological impacts. Reconnaissance activities focused on identifying the approximate location and extent of ecosystems and evaluating the potential for state- and federally-listed threatened or endangered (T/E) species at the site. Uptake of volatile constituents by plants, with subsequent transfer to grazing animals and food chain biomagnification, was not considered to be a significant exposure pathway. The ecological assessment for Pumphouse #2

found that the area was industrial and provided no natural habitat. Wildlife use was not expected, and no T/E species or populations were identified in the vicinity of Pumphouse #2. Further, the presence of asphalt and concrete at the site was determined to eliminate potential ecological exposure to soil contamination or fugitive dust. Inhalation of volatiles was not identified as a significant exposure pathway. The ecological risk assessment concluded that no further action would be required to minimize or eliminate potential ecological impacts.

The risk-based approach for the remediation of Pumphouse #2 will be consistent with the approach used in the baseline risk assessment to the maximum extent practicable given the likely use of affected media at and downgradient of Pumphouse #2.

3.1.3 Contaminants of Concern

This risk-based field test will address the specific chemical constituents that may drive potential risks and impact the final remedial design for Pumphouse #2. The COCs depend upon the nature of the source (i.e., suspected to be aged JP-4 and/or diesel fuel); the affected media (i.e., soil gas, surface and vadose soil, saturated soil, ground water, and potentially surface water); and the fate, transport, toxicity, and regulatory status of various fuel constituents. Details on the chemical composition of the suspected fuels and the physiochemical properties of these compounds are important factors that may influence fate and transport, and therefore desired remediation goals at the site.

JP-4 is a turbine engine fuel used exclusively by the U.S. Air Force. JP-4 petroleum products are made by blending various proportions of distillate stocks such as naptha, gasoline, and kerosene to meet performance specifications. The reported distillation range for JP-4 fuel is approximately 140-degrees-centigrade (°C) - 270°C. Most of the hydrocarbons fall in the range of C₄ to C₁₄. The major component categories (and their represented percentage by weight) in JP-4 are n-alkanes (32 percent), branched alkanes (31 percent), cyclo alkanes (16 percent), benzenes and alkyl benzenes (18 percent), and naphthalenes (3 percent). Other nonhydrocarbons are generally not important components in JP-4 by weight.

In contrast, diesel fuel is usually that fraction of petroleum that distills after kerosene in the 200°C to 400°C range. Diesel fuel is predominantly a mixture of C₁₀ through C₁₉ hydrocarbons. The major component categories (and their represented percentage by weight) in diesel fuel are straight-chain alkanes and cyclo alkanes (64 percent), aromatic hydrocarbons, including alkyl benzenes (35 percent), and olefinic hydrocarbons (1 to 2 percent). Other nonhydrocarbons are generally not important components in diesel fuel weight.

The environmental behavior of each group of specific hydrocarbons must be considered when identifying COCs for Pumphouse #2. For example, some compounds may be relatively mobile and nonpersistent in soil. These compounds may leach effectively from contaminated soil into underlying ground water and migrate as a dissolved-phase plume. Conversely, other compounds may be immobile under unsaturated conditions and may therefore not contribute to ground water contamination. In general, the high molecular weight hydrocarbons in diesel fuel are expected to be less mobile (lower aqueous solubility, higher sorption, and lower volatility) and more persistent (slower degradation) than the lower molecular weight hydrocarbons in JP-4 jet fuel.

Partitioning of chemical constituents from free-phase and residual contamination is an important fate mechanism that should be evaluated when identifying those compounds most likely to pose a risk to potential receptors and to require remediation. In general, migration of fuel

through soils will be retarded. Sorption is expected to be an important process for all the dominant hydrocarbon categories in both fuels, and can greatly limit the pattern and areal extent of pollution at the site over time. However, the aromatic hydrocarbon fraction of the source fuel has a slightly higher water solubility, which may make these constituents available for transport in infiltrating water and flowing ground water. Large releases of fuel can saturate the sorptive capacity of the soil, thus increasing the mass of specific constituents available for transport in the liquid phase. Once the fuel reaches ground water, the water solubility of each chemical constituent governs how it can partition into ground water. A fuel/water partitioning coefficient (K_{FW}) can be used to estimate the maximum concentration in ground water as a result of free-phase contamination. Available K_{FW} data support the observation that light aromatics such as the BTEX compounds represent the greatest fraction of diesel and jet fuels that could impact ground water quality (see Table 3.1) by dissolving in and being transported by ground water.

The fate of higher molecular weight hydrocarbons, which have lower water solubilities and lower vapor pressures than low molecular weight hydrocarbons, may be limited by the effectiveness of weathering processes such as evaporation and biodegradation. The pattern of pollution caused by this type of source is much less extensive in areal extent because only a limited mass fraction of the source may be available for transport in a dissolved-phase plume. However, the pollution from these sources can be much more persistent than that from lighter hydrocarbon sources.

Available data on the major hydrocarbon components of diesel fuel demonstrate a commonality with the hydrocarbons characteristic of JP-4 jet fuel. Concentrated fuels, if encountered at this site, are likely to be significantly weathered. Previous characterization efforts indicate that no SVOCs have been detected at concentrations in soil that may pose a health threat to base or construction workers. However, naphthalene has been detected at concentrations in ground water above its screening level. No chlorinated organic compounds have been detected at this site (see Section 2).

When establishing potential COCs for a site, it is also important to consider the availability and magnitude of toxicity values for each of the fuel constituents. Table 3.1 identifies typical compounds from the major classes of hydrocarbon groups possibly present in JP-4 and diesel fuel for which accepted human health toxicity values are available [e.g., from the Integrated Risk Information System (IRIS)]. No toxicity data or promulgated standards are available for most of the specific chemical compounds that could be present in the fuel. Toxicity values are available for the BTEX compounds and naphthalene. Toxicity data are available for carbazole, which previous site characterization data indicate may be present at the site. However, carbazole appeared in only one duplicate ground water sample from the site; the primary sample registered nondetect for carbazole. This contaminant is likely an artifact from the laboratory. This conclusion is further supported by the RFI analytical results summary, which reported a relative percent difference of 26 percent for the ground water samples from the only well with a detectable concentration of carbazole (HDR, 1994). This contaminant is not considered site-related and will not be a target analyte during this field test.

Therefore, the COCs for Pumphouse #2 which will be addressed as part of this field test include the BTEX compounds and naphthalene. This approach is consistent with that followed in the baseline risk assessment for PS-3, and will provide sufficient data to determine the type of remedial action required to protect human health and the environment from site-related contamination.

TABLE 3.1
SUMMARY OF FUEL/WATER PARTITIONING COEFFICIENTS
AND AVAILABILITY OF TOXICITY DATA
FOR THE MAJOR HYDROCARBON COMPONENTS OF JET AND DIESEL FUEL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Fuel Component	Fuel/Water Partition Coefficient	Available Tox. Data?
Benzene	231	YES
Toluene	895	YES
Ethylbenzene	3410	YES
o-xylene	3160	YES
m-xylene	3530	YES
p-xylene	2960	YES
Napthalene	24000	YES
1,1,3-trimethylcyclohexane	651000	NO
1,2,3,4-tetramethylbenzene	45800	NO
1,2,3-trimethylcyclopentane	276000	NO
1,2,4-trimethylbenzene	12270	NO
1,2,4-trimethylcyclopentane	276000	NO
1,2-dimethyl-4-ethylbenzene	45800	NO
1,3,5-trimethylbenzene	6490	NO
1,3,5-trimethylcyclohexane	651000	NO
1,3-diethylbenzene	45800	YES
1,3-dimethyl-5-ethylbenzene	45800	NO
1,4-dimethyl-2-ethylbenzene	45820	NO
1-methylnapthalene	27000	NO
1-methyl-2-ethylbenzene	7710	NO
1-methyl-2-ethylcyclohexane	9360	NO
1-methyl-2-isopropylbenzene	35100	NO
1-methyl-3-ethylbenzene	12200	NO
1-methyl-3-ethylcyclohexane	9366	NO
1-methyl-4-ethylbenzene	6690	NO
1-methyl-4-ethylcyclohexane	9360	NO
1-methyl-4-propylbenzene	45800	NO
2,2,3,3-tetramethylbutane	509000	NO
2,2-dimethylbutane	37800	NO
2,2-dimethylhexane	509000	NO
2,2-dimethylpentane	37000	NO
2,4-dimethylhexane	509000	NO
2,5-dimethylheptane	1860000	NO
2,5-dimethylhexane	509000	NO
2,6-dimethylnapthalene	593000	NO
2,6-dimethylundecane	33300000	NO
2-methylheptane	1330000	NO
2-methylhexane	430000	NO

TABLE 3.1 (Continued)
SUMMARY OF FUEL/WATER PARTITIONING COEFFICIENTS
AND AVAILABILITY OF TOXICITY DATA
FOR THE MAJOR HYDROCARBON COMPONENTS OF JET AND
DIESEL FUEL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Fuel Component	Fuel/Water Partition Coefficient	Available Tox. Data?
2-methylnapthalene	31000	NO
2-methyloctane	2460000	NO
2-methylpentane	61900	NO
2-methylundecane	12700000	NO
3,3-dimethylhexane	509000	NO
3,4-dimethylheptane	1860000	NO
3-methylheptane	1650000	NO
3-methylhexane	270000	NO
3-methyloctane	2450000	NO
3-methylpentane	66350	NO
4-ethylheptane	2450000	NO
4-methylheptane	647000	NO
4-methyloctane	15100000	NO
cis-1,2-dimethylcyclopentane	16600	NO
cis-1,3-dimethylcyclohexane	160000	NO
cis-1,3-dimethylcyclopentane	16600	NO
Cyclohexane	11700	NO
Dimethylcyclohexane	160000	NO
Ethylcyclopentane	16600	NO
Isobutane	14300	NO
Isopropylbenzene	9040	YES
Methylcyclohexane	55300	NO
Methylcyclopentane	16600	NO
n-butane	11000	NO
n-butylcyclohexane	35200	NO
n-decane	64400000	NO
n-dodecane	78600000	NO
n-heptane	365000	NO
n-hexane	91000	YES
n-nonane	7160000	NO
n-octane	2020000	NO
n-pentane	18800	NO
n-propylbenzene	7090	NO
n-tetradecane	18000000	NO
n-tridecane	48800000	NO
n-undecane	64400000	NO
trans-2,3-dimethylcyclopentane	16600	NO

3.1.4 Potential Source Areas and Release Mechanisms

As noted in Section 2, existing analytical data suggest that there may be more than one the contaminant source within Pumphouse #2. Underground fuel transfer lines and incidental surface spills may have contributed to subsurface contamination at the site. Additional site characterization efforts are recommended as part of this project to more fully delineate discrete source areas within Pumphouse #2. This detail is necessary to facilitate quantitative analyses of fate and transport processes, and evaluation and design of an appropriate remedial action for the site.

The contaminant release mechanisms conservatively incorporated into this CSM are: (1) volatilization into the atmosphere; (2) partitioning from soil or free product into ground water; (3) fugitive dust generation during scheduled construction activities; and (4) indirect release to surface water via ground water inflow. Surface runoff will not be considered a long-term significant release mechanism at the site given that all surface soil contamination is scheduled for removal in June 1995. This approach is consistent with the nature of contamination suspected at the site, the physical characteristics of the surrounding area, and the physiochemical properties of the COCs.

3.1.5 Fate and Transport Processes

Transport processes included in the CSM for Pumphouse #2 include (1) molecular diffusion through unsaturated soil, (2) air dispersion, and (3) ground water migration. Surface water exposure pathways are not expected to be complete at the site, but will be investigated as part of this field test to ensure that deep drainage ditches running along either side of Flightline Drive do not receive and transport site-related contamination. Plant uptake of contamination from soil and subsequent transport through food chain pathways is also not considered a significant fate process for volatile compounds. Because the BTEX compounds and naphthalene are not considered persistent in biota, there is limited risk to wildlife due to food chain dynamics. Further, there are no data on the toxicity of these compounds for plants, suggesting again that these compounds do not bioaccumulate or bioconcentrate. This approach is consistent with that followed in the baseline risk assessment for PS-3.

All of the COCs to be considered for Pumphouse #2 readily volatilize from water into air. Although the presence of asphalt and concrete at the site may effectively limit upward diffusion of contamination as soil gas, removal of site paving in June 1995 will change baseline soil conditions. The actual rate of emission from source soils and other soil medium at the site will be investigated as described in Section 4 of this work plan, and possibly modeled using the methods described in Sections 3.3 and 5.

The COCs for Pumphouse #2 are also expected to partition from contaminated unsaturated soil, which may contain fuel residuals, into the underlying ground water, and migrate downgradient as a dissolved-phase plume. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, adsorption), these dissolved-phase contaminants will be slowly removed from the ground water system by other naturally-occurring destructive mechanisms, such as biodegradation, abiotic oxidation, and hydrolysis. The effects of these processes on the dissolved-phase ground water plume will be investigated using a quantitative ground water and solute-transport model such as Bioplume II. Data collection and analysis requirements are discussed in Sections 4 and 5 of this work plan, respectively.

3.1.6 Potential Human and Ecological Receptors

Assumptions about land use form the basis for identifying potential receptors and potential exposure pathways. EPA (1991c) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be addressed in risk-based remedial decisions. Although hypothetical future residential land use provides the most conservative risk estimates, EPA risk assessment guidance materials state that this conservative approach may not be justifiable if the site is surrounded by an operating industrial facility that can be reasonably assumed to remain as an industrialized area. In these cases, the EPA recommends using other exposure scenarios, such as agricultural or light commercial/industrial, including a qualitative assessment of the likelihood that the assumed reasonable future land use will occur (55 *Federal Register* 710).

Malmstrom AFB is under the authority of the United States Air Force's (USAF's) Space Command and is home to the 341st Strategic Missile Wing and the 43rd Air Refueling Wing. Approximately 5,000 people work and/or live at Malmstrom AFB. Land use to the west and southwest of Malmstrom AFB is residential, commercial, and industrial. The areas immediately north, east, and south of Malmstrom are used to cultivate wheat crops and, to a lesser extent, to provide cattle rangeland. Current land use at Malmstrom AFB is primarily industrial (military). Malmstrom AFB provides on-base housing for military personnel and their families, but these facilities are limited to the northwestern quadrant of the base. There are no current or foreseeable plans or need to expand housing to other sections of the base.

Pumphouse #2 is under restricted-access control and is not suitable for uncontrolled recreation. It is likely that Pumphouse #2, which is located in the north-central portion of Malmstrom AFB, will remain as an industrial area with restricted access. Pumphouse #2 is scheduled for complete demolition in June of 1995. Should portions of Malmstrom AFB be scheduled for transfer to civilian authorities at sometime in the future, it is not likely that residential development will occur in Pumphouse #2 or within areas downgradient from Pumphouse #2 due to their close proximity to the flightline. The base is still active and is not likely to be available or desirable for residential development now or in the foreseeable future. Further, Pumphouse #2 is located close to the flightline and the industrial activities of this area.

It is important to note that the residential criteria are intended to be protective of any future uncontrolled land use, not just human habitation. This broad interpretation means that no controls would be imposed on any activity. While this is the most conservative (health-protective) exposure scenario, it is not reasonable and representative of the likely future uses of most of Pumphouse #2 and downgradient environs. It is probable that Pumphouse #2, a fuel storage and pumping facility that has been taken out of service and is scheduled for closure, will not be available for residential development, but will be maintained as an industrial property. Malmstrom AFB could reasonably apply more stringent land use restrictions or institutional controls to source areas and areas of higher contamination. In this case, this area should be conservatively evaluated using the light industrial/commercial and construction worker exposure scenarios. This approach would be consistent with that followed in the baseline risk assessment for PS-3.

Additionally, there are no current uses of shallow ground water on-base. Malmstrom AFB currently receives its domestic water supply from the Great Falls public water supply system. Further, the shallow ground water underlying Pumphouse #2 has been characterized as discontinuous and not a viable source of drinking water (HDR, 1994). The baseline risk

assessment for PS-3 did not consider ground water to be a part of any complete exposure pathway at the site. Therefore, on-base use of shallow ground water will not be factored into the exposure assumptions for current and future scenarios for Pumphouse #2 and environs immediately downgradient. It may be appropriate to include land use restrictions in the remedial alternative for these areas to ensure that the site remains industrial.

The remediation goals for Pumphouse #2 must also be protective enough to allow uncontrolled use of ground water resources in downgradient areas that may be available for unrestricted use (i.e., not maintained as an industrial facility; not under land use restrictions). Quantitative fate and transport analyses and exposure estimates will be conducted as part of this field test to ensure that established remediation goals are adequate to protect human health and the environment given the likely use of the land in question (i.e., industrial use only for Pumphouse #2 and areas immediately downgradient, and uncontrolled use further downgradient and off-base). The RFI and baseline risk assessment determined that contaminant impacts to deeper ground water resources are unlikely based on results obtained using the SESOIL fate and transport model. Model results indicated that shallow ground water contamination is not expected to affect the closest deeper aquifer unit capable of supporting a water supply system (located about 180 feet bgs) (HDR, 1994).

Current human receptors for contamination from Pumphouse #2 are assumed to include individuals working at the Pumphouse #2 site and in nearby areas at Malmstrom AFB, particularly those located downwind of Pumphouse #2. Pumphouse #2 is approximately 400 feet from other base office buildings and occupied work areas. Potential future human receptors will include both on-base industrial/commercial and construction (remedial) workers in Pumphouse #2 source areas and immediate environs, and on-base and off-base industrial/commercial workers and off-base residents in downgradient and downwind areas. This approach is consistent with both the likely use of land in the area and the PS-3 baseline risk assessment.

For the purposes of this project, ecological receptors will be limited to those terrestrial organisms that may contact or incidentally ingest contaminated soil. This exposure pathway is likely to be incomplete because the site ground cover currently consists of crushed rock, asphalt, and concrete, which preclude direct exposure to surface soil. Following the scheduled removal action in June 1995, surface soil will be accessible to terrestrial organisms. However, removal of all buildings, paving, and contaminated soil media as part of this action will effectively eliminate exposure to site-related contamination via direct contact or incidental ingestion. Ground water migration to or direct discharge into surface water will be investigated during the field work phase of this project. However, the potential surface water exposure point near the site is a deep storm water drainage ditch that is dry throughout much of the year and does not support aquatic organisms. Additionally, even if the data indicate that the COCs are transported to a potential exposure point, the chemicals may not be bioavailable. Available toxicity data for plants and animals do not suggest that VOCs such as the BTEX compounds and naphthalene can be bioaccumulated or bioconcentrated. Section 4 of this work plan identifies the need to obtain existing data on potential ecological receptors to determine what populations, if any, could be exposed to site contamination in the event that an exposure pathway were complete.

3.1.7 Exposure Points and Exposure Routes

An exposure point is a location at which any potentially exposed receptor could come into contact with site-related contamination. On-base contaminated media will be considered possible

exposure points only for those base personnel who currently or may in the future have access to the Pumphouse #2 area. Potential exposure points initially included in this CSM include Pumphouse #2 and the environs downgradient of the site (including nearby base office buildings and occupied work areas) that are likely to be affected by contamination at or migrating from source area(s). Several of these potential exposure points may be eliminated from the final evaluation should fate and transport data demonstrate that site-related contamination could not reach these locations (i.e., the exposure pathway is incomplete).

Probable exposure routes are dependent upon which receptors come into contact with what contaminated media. Exposure routes considered for human receptors in this CSM are limited to inhalation of contaminants volatilizing from soil, inhalation of VOCs accumulating within structures, incidental ingestion of contaminated soil (as particulates), and dermal contact with contaminated soil. Any direct exposure routes involving ground water will not be included as possible exposure routes for the following reasons: (1) shallow ground water is not likely to be encountered during normal construction activities, (2) shallow ground water is not currently used to meet on-base water demands, (3) existing sources of potable water are considered sufficient to meet expanding population requirements, and (4) future probable uses of Pumphouse #2 source areas and areas immediately downgradient will remain industrial (i.e., no use of shallow ground water). Ground water remediation goals will be established to protect human health and the environment in downgradient areas that may be open for unrestricted use of ground water resources. Acute exposure scenarios will not be considered as part of this project.

Probable exposure routes for ecological receptors will be limited to direct routes only; that is, routes of exposure for ecological receptors may include incidental ingestion of and dermal contact with contaminated soil, ingestion of surface water, and uptake via plant roots. As noted previously, however, it is possible that the ecological exposure pathways are incomplete. Further quantitative information on ground water migration is required.

3.1.8 Target Remediation Goals

The risk analysis approach to be used to screen, evaluate, select, design, and implement the most cost-effective remedial alternative at a site is addressed in Section 5 of this work plan. In general, a three-tiered approach will be used to determine appropriate remediation goals. This approach will assess (1) trigger or "evergreen" levels, (2) initial quantitative exposure assessment and chemical-specific remediation goals, and (3) more complex quantitative exposure assessment and chemical-specific remediation goals which include partial source removal.

Site-specific concentrations will first be compared to "evergreen" cleanup goals as an initial step to determine if continued investigation of remedial alternatives is warranted. If this comparison indicates the need for a more site-specific analysis (i.e., generic trigger levels are exceeded), then a quantitative exposure assessment designed to investigate governing fate and transport mechanisms and the potential effectiveness of intrinsic remediation will be completed (see Section 3.2). Results of this evaluation will be compared to site-specific remediation goals rather than "evergreen" levels to assess whether intrinsic remediation coupled with long-term monitoring will be sufficient to protect human health and the environment. If this second analysis suggests the need for additional remediation to meet cleanup goals for the site, the remedial alternative evaluation will be expanded to include an iterative, quantitative analysis of the effectiveness of other remedial technologies.

The goal of this tiered approach is to quickly identify which media and COCs may or will pose a risk to receptors so that a remedial alternative can be developed to minimize or abate these risks. Section 5 of the work plan contains a more detailed description of the risk analysis methods to be used in this project. The following sections briefly discuss several concepts that may drive the development of chemical-specific remediation goals for Pumphouse #2, and guide the risk analysis for the EE/CA report. The results of the baseline risk assessment will be incorporated into this process as appropriate. ✓

The first step in the tiered approach is comparing site concentrations to levels that would not trigger further action. Chemical-specific screening levels (formerly known as trigger levels) are defined by EPA or are some other promulgated standards that can be used to quickly identify contaminated media that require further investigation and eliminate other media that do not warrant additional study (e.g., EPA, 1993). Using chemical-specific screening levels at this first step focuses data collection and analysis on those chemicals, media, and areas within a site that may warrant concern, and eliminates unnecessary and costly investigation efforts. These chemical-specific screening levels are often called "evergreen" as they mark levels below which few people would argue about the need for remediation, regardless of site-specific circumstances. However, concentrations in environmental media that exceed these chemical-specific "evergreen" screening levels do not automatically designate the site as "dirty" or trigger the need for a response action. Exceedances indicate only the need for further study to establish whether site-specific concentrations are protective of human health and the environment (EPA, 1993). This approach is consistent with that used in the initial screening step of the baseline risk assessment completed for PS-3.

Table 3.2 presents the soil-specific screening (evergreen) levels for the COCs assuming unrestricted residential land use at Pumphouse #2. These soil screening levels are designed to be protective of human health. Development of soil "evergreen" levels that are protective of ground water quality (commonly called cross-media contamination levels) presume human ingestion at some close downgradient point. As this is not an appropriate or representative exposure assumption for Pumphouse #2 given current or probable future exposure conditions at the site, these levels represent the most conservative or worst-case screening levels. Chemical-specific screening levels most appropriately applied to this site would be designed to protect some other environmental quality, such as ground water further downgradient that may be used to meet potable water demands.

In any event, these soil "evergreen" levels will be used to determine which soils at Pumphouse #2 warrant additional study under the most conservative exposure assumptions. If concentrations in specific environmental medium at Pumphouse #2 do not exceed these "evergreen" levels, no further study or remedial action is warranted. Comparison of "evergreen" soil values for ethylbenzene and total xylenes to the soil contamination levels presented in Tables 2.1 through 2.3 indicate the need for additional study to quantify site-specific release and transport mechanisms and to develop final concentration goals that are protective of human health and the environment. Further, as noted previously, both benzene and ethylbenzene exceeded their "evergreen" ground water levels (federal MCLs) at several locations, suggesting the need for more evaluation. Naphthalene has also been detected in ground water at concentrations that exceed the health-based screening level derived as part of the baseline risk assessment for PS-3 (which was based on the conservative assumption that shallow ground water was the sole drinking water source of an adult resident).

TABLE 3.2
SUMMARY OF SOIL AND GROUND WATER "EVERGREEN" LEVELS
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Parameter	Maximum Soil ^{a/} (mg/kg)	Soil (Inhalation) (mg/kg)	Soil (Ground Water Protection) (mg/kg)	Maximum Ground Water ^{b/} (mg/L)	Ground Water MCLs (mg/L)
Benzene	0.023	3.2	0.1	890	5
Toluene	6.9	330	36	ND ^{c/}	1,000
Ethylbenzene	83	330	33	870	700
Xylenes	300	100	570	7,100	10,000
Napthalene	8.9	3,100	250	150	--

^{a/} Maximum concentration detected in soil at site.

^{b/} Maximum concentration detected in ground water at site.

^{c/} ND = Not detected.

Chemical-specific remediation goals are for specific medium and land use combinations. These chemical-specific remediation goals are more site-specific than "evergreen" screening levels in that they reflect site-specific conditions. These goals are necessary to identify, evaluate, and select an appropriate remedial alternative for Pumphouse #2. Identification of these chemical-specific, site-specific criteria depend upon which chemicals are present at the site, which environmental media are or may become contaminated, land use assumptions, and exposure assumptions. For example, chemical-specific remediation goals developed for Pumphouse #2 may include a fate and transport model component so that the cleanup goal can be met at a potential exposure point rather than requiring all media at the site to be remediated to this level. Final chemical-specific, site-specific remediation goals for Pumphouse #2 will be based on current and future exposure assumptions most appropriate for the site.

Chemical-specific concentration goals can either be risk-based or based on promulgated criteria. This demonstration will develop risk-based human health remediation goals for each COC for each contaminated environmental medium (e.g., surface soil, vadose zone soil, ground water) using carcinogenic and/or noncarcinogenic toxicity values, land use assumptions, and exposure assumptions. Risk-based remediation goals are calculated only for human receptors. Human health remediation goals may also be developed from appropriate promulgated standards. However, noncompound-specific remediation criteria such as TPH standards will not be identified as appropriate remediation goals for Pumphouse #2. Ecological remediation goals, if necessary, will be developed using soil (and possibly surface water) toxicological guidance or literature values. Further details on how site-specific remediation goals will be developed for Pumphouse #2 are presented in Section 5 of this work plan.

3.2 INTRINSIC REMEDIATION AND THE BIOPLUME II MODEL

After Pumphouse #2 has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any exposure pathway for human or ecological receptors is complete. The Bioplume II model has proved useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. The Bioplume II model (Rifai et al., 1988) can be used to evaluate critical ground water fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. Other quantitative models potentially suitable to simulate fate and transport in soil and air are presented in Section 3.3 of this work plan. More representative remediation goals that are protective of human health and the environment can be developed by quantitatively incorporating fate and transport processes into the evaluation of potential risks associated with site-related contamination. Quantitative fate and transport analyses and risk calculations can then be coupled to determine what level and extent of remediation is required. These calculations can also be useful in developing and negotiating final concentration goals that are protective of human health and the environment given the site-specific conditions.

An important consideration in determining whether fuel hydrocarbon contamination presents a substantial threat to human health and the environment and what type of remedial alternative will be most cost effective in eliminating or abating these threats is an accurate estimate of the potential for natural biodegradation of BTEX compounds in the soil and ground water. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons (Lee, 1988). This process occurs naturally when sufficient oxygen, other electron acceptors such as nitrate and sulfate, and nutrients are

available in the soil and ground water. The rate of natural biodegradation is generally limited by the lack of oxygen rather than by the lack of nutrients such as nitrogen or phosphorus.

Biodegradation of fuel hydrocarbons occurs when microorganisms catalyze the transfer of electrons from electron donors to electron acceptors during respiration. Electron donors can be organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons can be completely degraded or detoxified if they are used as the primary electron donor for microbial metabolism. Electron acceptors are elements or compounds that occur in relatively oxidized states and include oxygen, nitrate, sulfate, manganese, ferric iron, and carbon dioxide. Microorganisms exhibit a preferential use of terminal electron acceptors when metabolizing fuel hydrocarbons (Bouwer, 1992). Dissolved oxygen is used first as the prime electron acceptor. However, once the available oxygen is depleted and anaerobic conditions dominate in the subsurface, anaerobic microorganisms can use other electron acceptors in the following order of preference: nitrate, sulfate, manganese, ferric iron, and finally carbon dioxide.

The supply of oxygen to unsaturated soil can be renewed by vertical diffusion from the atmosphere. The supply of oxygen and other electron acceptors to a shallow, fuel-contaminated aquifer can be renewed by the influx of upgradient flow and the vertical diffusion of oxygen from the unsaturated soil zone into the ground water (Borden and Bedient, 1986). The rate of natural biodegradation in unsaturated soil and shallow aquifers is largely dependent upon the rate at which oxygen and other electron acceptors enter the contaminated media.

3.2.1 Biodegradation of Soil Contamination

The rate of vertical diffusion of oxygen into unsaturated, contaminated soil is a function of both the air permeability of the soil and the concentration gradient between the ambient atmosphere and the soil. In general, downward natural diffusion processes are rate-limiting and do not substantially enhance potential natural biodegradation processes within unsaturated soils. Natural biodegradation is not expected to rapidly reduce soil contamination. It is possible, however, to optimize both of these conditions by introducing oxygen into the unsaturated soil via a low-rate air injection system. This innovative technology, called bioventing, supplies oxygen to soil bacteria employed in the biodegradation of fuel hydrocarbons. The radius of influence of each air injection point depends upon the operational parameters of the engineered bioventing system and the physical, chemical, and biological characteristics of the contaminated, unsaturated soil. The positive influences of oxygenating shallow unsaturated soil are considered an engineered source removal technology. Results of bioventing pilot testing at Pumphouse #2 are described in Section 4.

3.2.2 Biodegradation of Dissolved-Phase Contamination

Several well-documented and widely-accepted numerical models are available for modeling the fate and transport of fuel hydrocarbons under saturated conditions and accounting for the influences of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. The positive effect of these processes on reducing the actual mass of fuel-related contamination dissolved in ground water has been termed intrinsic remediation. In some cases, intrinsic remediation will reduce the dissolved-phase contaminant concentrations to below concentration levels warranting remedial action (i.e., trigger or screening levels), even if little or no source removal/reduction is implemented. In situations where intrinsic remediation will not reduce contaminant concentrations to below these levels, it may be possible to negotiate less stringent,

site-specific final remediation goals that are still protective of human health and the environment given the type and magnitude of exposures most representative of current and potential future site conditions.

Intrinsic remediation advantages are as follows: (1) contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment; (2) current pump-and-treat technologies are energy intensive and generally not as effective in reducing residual contamination; (3) the process is nonintrusive (i.e., involves minimal drilling and support equipment) and allows continuing use of the land during remediation; (4) current engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation because contaminants may be transferred into the atmosphere during remediation activities; and (5) intrinsic remediation is far less costly than conventional, engineered remedial technologies. The main limitation of intrinsic remediation is that it is a long-term solution which requires regular monitoring to confirm its progress.

To estimate the impact of natural biodegradation on the fate and transport of BTEX compounds in ground water at a site, two important lines of evidence will be demonstrated as part of this project (Wiedemeier et al., in progress). The first is soil and ground water monitoring to document the ongoing biodegradation of contaminants. Dissolved-phase concentrations of biologically-recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters such as ground water seepage velocity and dilution to demonstrate that a reduction in the total contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass-balance calculations to show that a decrease in contaminant and electron acceptor (e.g., oxygen, nitrate, sulfate) concentrations can be correlated to increases in metabolic fuel degradation byproduct concentrations (e.g., carbon dioxide, methane, ferrous iron). With this site-specific information, the Bioplume II computer model can be used to simulate the transport of dissolved-phase BTEX compounds under the influence of natural biodegradation. Microcosm studies will not be a component of this field test.

The Bioplume II model is based upon the US Geological Survey (USGS) two-dimensional (2-D) solute transport model MOC, which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. However, as part of this demonstration project, the biodegradation of fuel contamination will be activated by a superimposed plume of both oxygen and nitrate. Work completed as part of the natural attenuation (intrinsic remediation) demonstration program, also sponsored by AFCEE, suggests that these compounds are the primary electron acceptors at fuel-contaminated sites based on both thermodynamic and kinetic considerations. Use of both oxygen and nitrate in the Bioplume II model should provide a better estimate of the effectiveness of natural attenuation processes at the site in minimizing contaminant migration and reducing contaminant mass and toxicity. Use of both primary electron acceptors should also provide a better estimate of response time. Use of oxygen as the only electron acceptor can seriously underestimate the effects of natural degradation processes. The impact of including both electron acceptors in the Bioplume II model for this site may be a reduction in the source removal activities and time required to achieve site-specific remediation goals.

Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the ground water and once for the electron acceptor plume. The two plumes are then

combined using superposition at every particle move to simulate biological reactions between fuel products and the electron acceptors. Using even the most realistic worst-case data, Bioplume II generally predicts very limited migration of BTEX plumes due to natural attenuation processes. Bioplume II has been used to simulate the potential effectiveness of intrinsic remediation at several sites (e.g., Wilson et al., 1986; Chiang et al., 1989; Rifai et al., 1988; Malone et al., 1993; Wiedemeier et al., 1993).

The risk-based approach to remediation is aimed at providing scientific evidence in support of the positive effects of intrinsic remediation and other innovative source removal technologies. The type and magnitude of these effects will be factored into the development of a final remedial alternative for the site. It is likely that intrinsic remediation alone will be insufficient at many fuel hydrocarbon-contaminated sites to reduce or eliminate contaminant migration and receptor risks. Other innovative source removal technologies, such as bioventing, will be included in the fate and transport calculations, risk analysis, and remedial design for Pumphouse #2 as necessary to ensure that the final remedial alternative will protect current and future receptors from adverse exposures to any site-related contamination (e.g., soil gas, soil, and ground water). Section 5 provides more detail on how quantitative models such as Bioplume II will be used to assess how effectively various remedial technologies eliminate or reduce contaminant migration and receptor risks.

3.3 OTHER QUANTITATIVE FATE AND TRANSPORT MODELS

The Summers model can be used to evaluate the potential impact of contaminated soil on ground water quality via downward precipitation infiltration (EPA, 1989a). This model may be useful to determine the potential for cross-media contamination, which may act as a continuing source of ground water contamination. The Summers model assumes that a percentage of precipitation at the site will infiltrate and desorb contaminants from the soil based on equilibrium partitioning between soil and liquid phases. Application of a fuel/water partitioning model such as that developed by Bruce et al. (1991) may also be required to provide a conservative estimate of how light aromatic hydrocarbons such as the BTEX compounds dissolve into ground water.

Soil gas concentrations cannot be directly used to assess potential air impacts without first accounting for VOCs diffusing upward through the vadose zone and their dilution in the atmosphere or during air exchanges in buildings. ES will use flux isolation chambers to collect air samples from the ground surface at several locations throughout the area. These actual flux samples taken over areas of known soil contamination will be used to estimate concentrations of VOCs entering the atmosphere and potentially entering occupied buildings via diffusion. Preferential soil gas migration routes (e.g., pipelines and utilities) will also be considered, as necessary. Additional details on soil flux methods are included in Section 4. Several air diffusion and dispersion models recommended by the EPA (1992c) are available to determine air concentration levels in the atmosphere at several exposure points and accumulating in buildings. Actual flux concentrations will be coupled with a distance-related attenuation/dispersion equation to estimate the concentration in the air that an off-site receptor may reasonably be expected to inhale. To estimate VOC concentrations in the atmosphere due to molecular diffusion through contaminated soil, this flux rate will be incorporated into a simple virtual upwind point-source dispersion equation recommended by the EPA (1981 and 1992c) to characterize potential air quality impacts.

To determine if soil and ground water concentrations could present a threat to individuals who may work or reside within buildings constructed on or adjacent to Pumphouse #2, it may be necessary to use a simple diffusion/intrusion model to estimate the average annual VOC concentration that could accumulate in buildings due to upward contaminant flux from soil. The results of the flux monitoring described previously are then used as the input parameters for this model, which minimizes the effects of dispersion under atmospheric conditions by containing the flux within a structure. All of these models have been used successfully at many sites to quantitatively estimate the fate, transport, and impact of soil and ground water contamination on air quality. Because this site is located near the flightline and active re-fueling areas, ambient or "background," concentrations of VOCs must be statistically verified to accurately account for VOCs emitted from soil contamination.

SECTION 4

PROPOSED SITE CHARACTERIZATION ACTIVITIES

To develop and implement of a risk-based remedial action for Pumphouse #2, additional site-specific environmental data will be collected. Soil gas, soil, ground water, and surface water or sediment will be sampled to (1) delineate the nature and extent of contamination, (2) support fate and transport analyses, (3) develop appropriate exposure-point concentrations to compare to final remediation goals, and (4) evaluate and design an appropriate remedial alternative for the site. A sufficient number of samples from background and contaminated areas will be collected and analyzed for individual and indicator compounds to accurately assess the risk to human health and the environment posed by the site and to demonstrate the attainment of final cleanup levels. ✓

Noncompound-specific analytical procedures (e.g., TRPH analysis) will be used as screening methods to aid in the determination of the lateral and vertical extent and volume of contaminated media at Pumphouse #2. These analyses will be supplemented with compound-specific analyses. Development of a risk-based remedial alternative for Pumphouse #2 will require an analysis of the potential chemical-specific threats posed to human health and the environment by individual compounds. Therefore, analytical data collected for the site will include a determination of the presence and concentration of individual chemicals. ✓ ✓ ✓

4.1 GENERAL DATA NEEDS

Several data needs were identified as a result of developing the CSM for Pumphouse #2 and assessing the input requirements for the quantitative fate and transport models. These data are necessary to prepare an EE/CA report in support of a risk-based remedial action for Pumphouse #2. Additional soil gas, soil, ground water, and surface water or sediment sampling will be performed. New ground water monitoring wells will be installed. Aquifer testing and limited source removal technology feasibility analyses will also be completed. Any additional existing information not incorporated into this work plan will also be reviewed and used to the extent practicable to evaluate and design an appropriate remedial alternative for Pumphouse #2 which eliminates or abates risks to human health and the environment to the maximum extent practicable. The site characteristics listed below will be determined during the field work phase of the risk-based approach to remediation.

Soil gas measurements will be used to determine the following site characteristics:

- Air-filled porosity of the first 2 feet of soils;
- Estimated flux rate of VOCs to the surface, if any;
- Efficiency of ongoing bioventing test in reducing soil gas BTEX;
- Soil gas oxygen concentrations by depth (current and before bioventing tests);
- Soil gas carbon dioxide concentrations by depth (current and before bioventing tests); and
- Concentrations of TVH and BTEX compounds by depth (current and before bioventing tests).

Characteristics of surficial soil, defined as the top 2 feet of soil at the site, to be determined through soil sampling and analysis include:

- Estimated effective porosity and air permeability;
- Total organic carbon (TOC) content and pH;
- Nature and extent of any surficial soil contamination; and
- Concentrations of TRPH and the BTEX compounds.

Vadose zone (unsaturated) and phreatic zone (saturated) soil characteristics to be determined include:

- Detailed stratigraphic analysis of subsurface media;
- Air-filled and/or effective porosity;
- Estimated moisture content (unsaturated only);
- TOC content and pH;
- Concentrations of TRPH and the BTEX compounds by depth (current and before bioventing tests);
- Estimated vertical extent of free product smear zone (if present);
- Radius of oxygen influence of existing bioventing pilot system; and
- Estimation of fuel biodegradation rates within the bioventing radius of influence.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the ground water surface;
- Depth from measurement datum to the base of the shallow saturated zone (i.e., the top of the glacial till) where feasible;
- Location of potential ground water recharge and discharge areas;
- Hydraulic conductivity of the glacial till through slug tests; and
- Dispersivity (estimated).

Chemical hydrogeologic characteristics to be determined include:

- Determination of extent and thickness of free product, if any;
- Dissolved oxygen, sulfate, and nitrate concentrations;
- Dissolved carbon dioxide, total alkalinity as carbonate and bicarbonate, methane, and ferrous iron concentrations;
- Concentrations of each of the BTEX compounds, total hydrocarbons, and screening for naphthalene;
- Temperature;
- Specific conductance;
- TOC content and pH; and
- Chemical analysis of free product, if any, to determine mass fraction of BTEX and polynuclear aromatic hydrocarbon (PAH) compounds.

Surface water physical and chemical characteristics to be determined include:

- Estimated flow rate at point of ground water inflow, if any;
- pH, TOC content, and total suspended sediments (TSS);
- Temperature; and
- Dissolved and total concentrations of the BTEX compounds and screening for naphthalene.

TABLE 4.1

**SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA**

Matrix: Soil Gas

Analysis	Method	Required		Field or Laboratory	Analysis Classification*	Data Use
		Detection Limit	Limit			
Carbon dioxide content	Direct reading meter	0.2%		F	A	To determine carbon dioxide gradient with depth and to infer biological degradation of fuel- related compounds.
Oxygen content	Direct reading meter	0.2%		F	A	To determine oxygen gradient with depth, the presence or absence of aerobic degradation processes, and/or the effect of engineered systems on increasing oxygen content in soil.
Fuel hydrocarbon vapor content	Total combustible hydrocarbon meter	1 ppmv		F	A	A field screening method to determine extent of soil contamination, the need for source removal, and the effect of source removal techniques on soil contamination.
Benzene	EPA TO-3	0.01 µg/L		L	B	Quantitative analysis to determine the nature and extent of soil contamination, the potential for adverse air quality effects, the need for source removal, and the effect

TABLE 4.1 (Continued)

**SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA**

Matrix: Soil Gas

Analysis	Method	Required Detection		Field or Laboratory	Analysis Classification *	Data Use
		Limit				
Toluene	EPA TO-3	0.01 µg/L	L	B	of source removal techniques on specific compounds. Same as benzene. Same as benzene. Same as benzene. Noncompound-specific analysis to determine the extent of soil contamination, the need for source removal, and the effect of source removal techniques at reducing fuel-related contamination.	
Ethylbenzene	EPA TO-3	0.01 µg/L	L	B		
Xylene	EPA TO-3	0.05 µg/L	L	B		
TVH	EPA TO-3	0.1 ppmv	L	B		

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Soil

Analysis	Method	Required Detection Limit		Field or Laboratory	Analysis Classification*	Data Use
Total combustible hydrocarbons	Direct reading meter	low	reading 1 ppmv	F	A	A field screening method to determine the extent of soil contamination, the need for source removal, and the effect of source removal techniques on soil contamination.
Benzene	GC Method SW8020	10 µg/kg		L	B	Quantitative analysis to determine the nature and extent of soil contamination, the mass of contaminant present, the degree of weathering, the need for source removal, and the effect of source removal techniques on specific compounds.
Toluene	GC Method SW8020	10 µg/kg		L	B	Same as benzene.
Ethylbenzene	GC Method SW8020	10 µg/kg		L	B	Same as benzene.
Xylene	GC Method SW8020	30 µg/kg		L	B	Same as benzene.
Trimethylbenzene isomers	GC Method SW8020	10 µg/kg		L	B	Tracers to aid data evaluation on soil contamination and potential impact to ground water.
pH	E150.1	0.2		L	C	Aerobic and anaerobic processes are pH-sensitive.

TABLE 4.1 (Continued)
SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Soil

Analysis	Method	Required		Field or Laboratory	Analysis Classification*	Data Use
		Detection Limit				
TRPH	Modified SW8015	10 mg/kg		L	C	A noncompound-specific method to determine the extent of soil contamination, the need for source removal, and the effect of source removal techniques on soil contamination.
TOC	Modified SW9060	20 mg/kg		L	D	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of fuel-related compounds in ground water is dependent upon the amount of TOC in phreatic soils; the rate of release of fuel-related compounds from the source to ground water is in part dependent on the amount of TOC in the unsaturated soil.
Classification	ASTM D422	--		L	D	Aids evaluation of potential contaminant migration behavior and remedial technology effectiveness.

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Soil

Analysis	Method	Required		Field or Laboratory	Analysis Classification*	Data Use
		Detection Limit				
Moisture	ASTM D2216	--		L	D	To determine effective porosity and ability of material to transport contamination as dissolved-phase; aerobic and anaerobic microorganisms require moisture.

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Ground Water

Analysis	Method	Required		Field or Laboratory	Analysis Classification*	Data Use
		Detection Limit				
Depth to water	Water probe	0.01 ft		F	A	Hydrogeological characterization; well development.
Thickness of product	Oil/water probe	0.01 ft		F	A	To determine extent of potential continuing source to ground water, the mass of source contamination, and the need for source removal.
Temperature	direct reading/ E170.1	0.2°C		F/L	A	Well development.
DO content	Downhole DO probe	0.2 mg/L		F	A	Data input to Bioplume II model; depleted levels generally indicate inhibited aerobic degradation and potential presence of anaerobic degradation processes; concentrations less than 1 mg/L correlate well to elevated dissolved- phase BTEX contamination.
pH	direct reading/ E150.1	0.2		F/L	A	Aerobic and anaerobic processes are pH-sensitive.
Benzene	GC Method SW8020	1 µg/L		L	B	Primary compound-specific analytes used to estimate and monitor intrinsic remediation; used to determine nature and extent of

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Ground Water

Analysis	Method	Required Detection Limit		Field or Laboratory	Analysis Classification*	Data Use
Toluene	GC Method SW8020	1 µg/L		L	B	Same as benzene.
Ethylbenzene	GC Method SW8020	1 µg/L		L	B	Same as benzene.
Xylenes	GC Method SW8020	3 µg/L		L	B	Same as benzene.
Trimethylbenzene isomers	GC Method SW8020	--		L	B	To monitor and correct for plume dilution effects in Bioplume II model setup.
Napthalene	HPLC Method SW8310	5 µg/L		L	C	To determine nature and extent of such contamination; the degree of weathering; and to establish and demonstrate compliance with site-specific remediation goals.
Alkalinity	HACH-Colorimetric	--		F	C	To verify that ground water samples are obtained from same system and to measure the buffering capacity of the aquifer.

TABLE 4.1 (Continued)
SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Ground Water

Analysis	Method	Required	Field or Laboratory	Analysis Classification*	Data Use
		Detection Limit			
Nitrate	HACH-Colorimetric	2 mg/L	F	C	Secondary substrate (electron acceptor) for microbial respiration if oxygen is depleted; data input to Bioplume II model.
Sulfate	HACH-Colorimetric	--	F	C	Potential substrate for anaerobic microbial respiration; will be used semi-quantitatively when evaluating intrinsic remediation.
Carbon dioxide	HACH-Colorimetric RSKSOP 147	--	F L	C	Carbon dioxide can be an electron acceptor for anaerobic microbial respiration; the presence of free carbon dioxide dissolved in ground water is unlikely given natural buffering capacities. If detected, concentrations will be compared to background levels to determine if they are elevated, which could suggest aerobic degradation.
Methane	RSKSOP 147	--	L	C	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis). If detected,

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Ground Water

Analysis	Method	Required Detection		Field or Laboratory	Analysis Classification*	Data Use
		Limit				
Total hydrocarbons	GC Method SW8015	--		L	C	concentrations will be compared to background levels to determine if they are elevated, which could suggest anaerobic degradation.
						To estimate the extent of contamination and to monitor the reduction in fuel-related contamination due to natural attenuation.
Ferrous iron (Fe ²⁺)	HACH-Colorimetric	0.06 mg/L		F	C	May indicate an anaerobic degradation process as a result of depletion of other electron acceptors such as oxygen and nitrate.
TOC	Modified SW9060	--		L	D	To estimate the sorptive capacity of the aquifer; data input to Bioplume II.
Aquifer slug test	Appendix A, Section A.5	--		F	D	Hydrogeological characterization

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

TABLE 4.1 (Continued)

SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA

Matrix: Surface Water

Analysis	Method	Required Detection Limit	Field or Laboratory	Analysis Classification *	Data Use
Temperature	direct reading/ E170.1	0.2°C	F/L	A	Hydrological characterization.
pH	direct reading/E170.1	0.2	F/L	A	Fate and transport of BTEX compounds in surface water is pH-sensitive; required remediation goals are pH-dependent.
Benzene	GC Method SW8020	1 µg/L	L	A	To determine nature and extent of contamination, potential for cross-media contamination, and compliance with remediation goals for surface water.
Toluene	GC Method SW8020	1 µg/L	L	A	Same as benzene.
Ethylbenzene	GC Method SW8020	1 µg/L	L	A	Same as benzene.
Xylenes	GC Method SW8020	3 µg/L	L	A	Same as benzene.
Trimethylbenzene isomers	GC Method SW8020	--	L	A	Possible tracers to monitor the reduction in chemical contamination due to dilution.
TOC	Modified SW9060	--	L	A	Fate and transport of BTEX and other fuel-related compounds influenced by presence of TOC;

TABLE 4.1 (Continued)

**SOIL GAS, SOIL, AND WATER SAMPLING PROTOCOL
EE/CA WORK PLAN
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA**

Matrix: Surface Water

Analysis	Method	Required		Field or Laboratory	Analysis Classification *	Data Use
		Detection	Limit			
Napthalene	HPLC Method SW8310	5 µg/L	L	A		required remediation goals are also dependent upon TOC. To determine nature and extent of such contamination and to demonstrate compliance with remediation goals.

* Analysis classification groups analysis requirements by method or groups a suite of analytical requirements by expected frequency. A = easily accomplished, required; B = more substantial analytical requirements, required; C = focused analytical requirements to satisfy fate and transport data needs, limited; D = isolated tools, very limited.

Table 4.1 lists the chemical analytical protocol for each of the environmental media to be sampled in support of a risk-based remedial design for Pumphouse #2. This table also presents the detection limits required to support quantitative fate and transport analyses and calculation of exposure-point concentrations to compare to final remediation goals. Additional site-specific data necessary to support preparation of the EE/CA report include (1) general climatic data, including prevailing wind speed and direction, average precipitation (as snow and rain), and temperature range; (2) existing and proposed land use plans for portions of Malmstrom AFB, including Pumphouse #2 and downgradient environs; (3) presence or suspected presence of sensitive subpopulations such as downgradient and downwind office buildings, T/E species, or special-concern habitats; (4) ground water well locations and use information for areas likely to be affected by ground water migration; (5) identification of preferential migration pathways in subsurface; and (6) additional site-specific data necessary to justify site-specific land use and exposure assumptions.

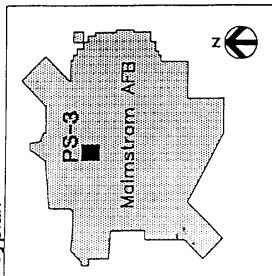
4.2 SAMPLING STRATEGY

The existing bioventing pilot system at Pumphouse #2, which consists of one bioventing well and three monitoring points, will be turned off at least 30 days before initiation of field work described herein to ensure data are representative of passive (at equilibrium) conditions at the site. Field investigation efforts will be completed in the following sequence: (1) soil gas sampling for compound-specific analysis; (2) soil gas flux sampling; (3) drilling, soil sampling, and well installation in least contaminated areas; (4) drilling, soil sampling, and well installation in most contaminated areas; (5) well development; (6) collection of physical ground water data from least to most contaminated areas, excluding slug tests; (7) collection of ground water samples from least to most contaminated areas for chemical analyses; (8) collection of surface water samples or sediment samples; and (9) slug tests. Several of these activities can be conducted concurrently at the discretion of the ES site manager to expedite the field work phase of this project. However, care must be taken to minimize cross-contamination and other medium-specific effects that could complicate data evaluation. Appendix A to this work plan is the detailed site-specific SAP. Specific procedures and protocols for each type of field activity to be completed at Pumphouse #2, including quality assurance requirements, are presented in the SAP.

4.2.1 Soil Gas Sampling

Shallow soil gas probes will be used to better define the areal extent of soil gas contamination and the potential for lateral and upward diffusion of soil contamination in the soil-pore vapors at the site. The shallow soil gas probe will be pushed to a depth of approximately 2 to 3 feet bgs, soil gas will be withdrawn, and analyzed for concentrations of the BTEX compounds. The data collected using the shallow soil gas probes will be used to supplement soil gas measurements from permanent vapor ^{monitor} extraction points installed at Pumphouse #2 as part of the bioventing pilot test. It is anticipated that four to five temporary soil gas locations will be sampled along the fence to the northwest of Building 245 and along both sides of Flightline Drive. These soil gas locations are indicated on Figure 4.1. Shallow soil gas samples will be analyzed as prescribed in Table 4.1. Soil gas samples also will be collected from the three existing vapor monitoring points (MPA,

Keyplan



Legend

- | | | |
|---|---------|--|
| ● | SB — 01 | Soil Boring Location |
| ● | SB — 02 | Soil Boring Completed as a Groundwater Monitoring Well |
| ● | SS — 01 | Surface Soil Sampling Location |
| ● | | Proposed Soil Gas Sampling Location |
| ○ | | Proposed Soil Flux Sampling Location |

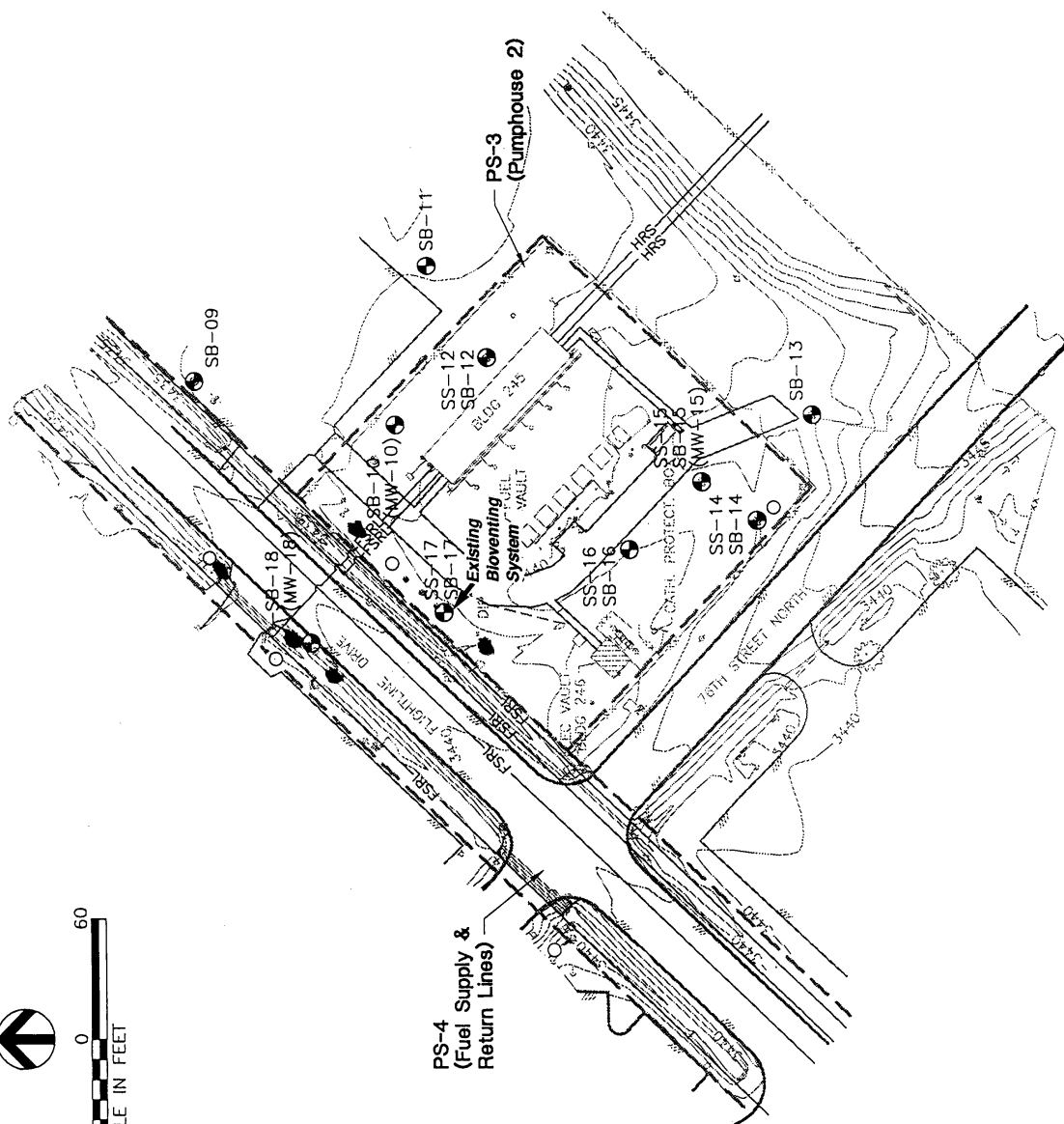
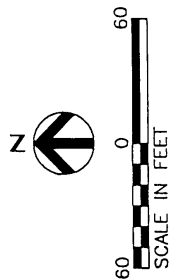
FIGURE 4.1

LOCATION OF ADDITIONAL SHALLOW SOIL GAS AND SOIL FLUX SAMPLES

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

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MPB, MPC) associated with the ongoing bioventing pilot study at the shallow depth intervals (approximately 4 feet bgs). Flux sampling will also be conducted at five separate locations, as shown in Figure 4.1. Two of these locations are in areas of known subsurface soil and ground water contamination along Flightline Drive. Two sample locations will be placed in areas where contaminated ground water has migrated underneath clean soil. The purpose of flux sampling in these four areas is to accurately estimate the upward diffusion of VOCs from the soil from the source areas. The one remaining sample location has been selected in a grassy areas several hundred feet upgradient of the source area. The purpose of flux sampling in this area will be to determine background concentrations of contaminants.

Soil gas and flux sampling will be conducted by qualified ES scientists and technicians trained in the conduct of soil gas shallow probe sampling and soil flux measurement. In addition, sampling personnel will have thoroughly reviewed this work plan, including Appendix A, prior to sample acquisition and will have a copy of both available onsite for reference.

4.2.2 Soil Sampling

Soil drilling and sampling will also be necessary to characterize the nature and extent of vadose and phreatic zone soil contamination at and immediately downgradient of Pumphouse #2. Continuous soil cores will be taken at 12 locations identified on Figure 4.2. Permanent bioventing wells or ground water monitoring wells will be installed at each of these soil boring locations. *Const. Details ?* If it becomes apparent during drilling activities that certain areas are not contaminated (based on field screening), borings will not be completed as wells. The soil samples selected for analytical analysis will be subsampled for chemical analysis from a 2-foot core interval. Soil cores will be carefully evaluated to determine the stratigraphy of the sample location and the vertical depth of any measurable or visible contamination, possibly sampled for laboratory analyses, and then composited for headspace readings. A maximum of two soil samples for laboratory analysis will be taken per soil core. If it becomes apparent during the site investigation that all 12 borings will not be drilled, more than two samples may be collected from other contaminated locations. The location of the required samples will depend on the extent of apparent soil contamination (as indicated by olfactory, visual, or volatile organic analyzer inspection). Soil borings that exhibit an interval of soil contamination exceeding 2 feet located above the water table will be converted to 4-inch-diameter bioventing wells for potential use in source removal. All others will be converted to 2-inch-diameter permanent ground water monitoring wells. Soil samples will be analyzed as prescribed in Table 4.1. The new soil sampling locations were selected to provide additional information about site stratigraphy, background concentrations, and the extent of the contamination at the site.

Soil sampling will be conducted by qualified ES scientists and technicians trained in the conduct of soil drilling, sampling, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan, including Appendix A (the SAP), prior to sample acquisition and have a copy available onsite for reference.



FIGURE 4.2

**LOCATION OF PROPOSED SOIL,
GROUNDWATER AND SURFACE
WATER SAMPLE LOCATIONS**

EE/CA Work Plan

Risk-Based Approach to Remediation

Pumphouse #2, Malmstrom AFB, Montana

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4.2.3 Ground Water and Product Sampling

New ground water monitoring wells will be constructed at each soil boring location not completed as a bioventing air injection well to further delineate the nature and extent of ground water contamination at the site. Additionally, five temporary ground water monitoring points will be installed at the site, as shown on Figure 4.2. These points will be driven to below the ground water surface using a hydraulic hammer, and then sampled using a peristaltic pump. After sample collection, the points will be removed. Samples collected by this method will be field screened as prescribed in Table 4.1 and sent for laboratory analysis of the BTEX compounds ^{and naphthalene}. This field screening will allow further characterization of ground water at the site without the time and expense of drilling and installing new wells. All new wells will be developed and sampled for laboratory analysis. Additionally, three existing ground water monitoring wells will be resampled to further delineate probable source areas of contamination, the areal extent of the dissolved-phase plume, and other hydrogeologic characteristics. All wells will be used to characterize physical characteristics, such as depth to the ground water surface.

Emphasis will also be placed on defining the estimated extent of any remaining free fuel product that may act as a continuing source of soil gas and ground water contamination. Free product can be physically identified using an oil/water interface probe. Moreover, any ground water samples showing a benzene concentration equal to or greater than 178 mg/L (10 percent of benzene's maximum solubility in water) will be operationally defined as potential fringe areas to free-phase contamination (or underlying significant residual soil contamination).

Figure 4.2 identifies the locations of the new ground water monitoring wells. Ground water samples collected as part of this field effort will be analyzed as prescribed in Table 4.1. Data from previous investigations will be incorporated into the final analysis to the extent practicable to avoid unnecessary duplication of field results. If encountered, at least one free-phase product sample will be recovered and subjected to a full chemical constituent analysis to determine how free fuel constituents will partition into the ground water and contribute to the dissolved-phase plume.

4.2.4 Aquifer Testing

Aquifer testing will be completed using existing ground water monitoring well MW-18 and three new wells to be installed during the field investigation. The three wells to be used in aquifer testing will be selected in the field. Both bioventing and permanent ground water monitoring wells may be used for this purpose given that bioventing wells will be completed below the ground water surface. The objective of these tests is to provide further information on the hydrogeologic conditions specific to Pumphouse #2 and the areas suspected to be immediately downgradient of probable source areas. These field tests ^{are} necessary to support quantitative fate and transport analyses using the Bioplume II model. OK - slug tests

4.2.5 Surface Water or Sediment Sampling

Provided sufficient flow and volume exists, surface water grab samples for laboratory will be taken at four discrete locations up- and downgradient of Pumphouse #2. Two samples will be

collected from each of the drainage ditches on either side of Flightline Drive. On each side, samples will be collected upgradient and downgradient of the site. Figure 4.2 identifies the approximate locations of the proposed surface water samples. If there is insufficient water flow or volume in the ditches to collect representative water samples, culvert sediment samples will be collected from the bottom of the ditches at the proposed sample locations and submitted for chemical analysis as a soil sample. The purpose of this sampling is to determine whether there is hydraulic communication between ground water and ephemeral surface water in the area.

4.3 SOURCE REMOVAL FEASIBILITY TESTING

It is anticipated that some level of soil or ground water remediation may be required to reduce the source of BTEX contamination migrating away from the Pumphouse area and to reduce potential exposures to these compounds. Recent soil sampling at 10 locations in the immediate vicinity of Pumphouse #2 revealed an average total BTEX concentration of 48.5 mg/kg exists in the 4- to 6-foot bgs interval. The sample from the boring for MW-18 had the highest overall concentration, with 383 mg/kg of BTEX (HDR, 1994). Because this soil contamination may represent a significant source of future ground water and soil gas contamination, some level of soil remediation may be warranted.

In addition to intrinsic remediation, three active remediation methods will be considered during the EE/CA process. The three technologies are *in situ* bioventing of soils, limited free product recovery, and air sparging to promote VOC removal from the ground water and to add DO to the aquifer. Additional data are required to complete an accurate evaluation of these source removal methods.

4.3.1 Initial Bioventing Results

Bioventing is an innovative technology which uses low rates of air injection to supply oxygen to soil bacteria employed in the biodegradation of fuel hydrocarbons. The Air Force has successfully used bioventing for remediation of several JP-4 spill sites (Downey et al., 1993). A bioventing pilot test was initiated at Pumphouse #2 in October of 1993 to determine the feasibility of using this technology for reducing BTEX and total petroleum hydrocarbons in contaminated site soils (ES, 1993). One air injection vent well (VW-1) and three vapor monitoring points were installed near soil boring SB-17 (Figure 4.2).

Test procedures outlined in the Air Force bioventing protocol document (Hinchee et al., 1992) were followed, and included an air permeability test, oxygen influence test and *in situ* respiration test. Results of the air permeability test indicated an average soil permeability of 18 darcys, with a pressure influence extending at least 25 feet from the air injection well. Air flow through fine-grained soils at 4 feet bgs was observed, as was an increase in soil gas oxygen. Unfortunately, the ground water surface was only 5.2 feet bgs during the test, and the oxygen influence in deeper soils could not be measured. As the water table drops during the summer and fall, the radius of oxygen influence in deeper soils is also expected to exceed 25 feet.

Initial soil gas measurements indicated depleted oxygen conditions in the soil were limiting the rate of biological fuel degradation. The biological uptake of oxygen by soil bacteria was measured at the 4-foot depth interval by injecting air into vapor monitoring points and then

measuring the uptake of oxygen by soil bacteria. Rapid uptake was observed at all points, indicating a significant population of hydrocarbon-degrading bacteria in the soil. Based on oxygen uptake rates, potential hydrocarbon degradation was estimated at 2,240 to 2,780 mg of fuel per kg of soil per year (ES, 1993).

The 1-year performance of the bioventing system will be analyzed during the upcoming fieldwork. If the ground water table has dropped, the radius of oxygen influence will be verified in the deeper (> 6 feet bgs) vapor monitoring points. Soil gas will be analyzed to estimate the reduction in soil BTEX that has occurred during the first year of pilot testing of this source removal technology.

4.3.2 Free Product Recovery

If analysis reveals that a significant BTEX source remains as free product, it is possible that product recovery will be required in the source area. To date, no free product has been observed in any of the wells at Pumphouse #2. ES will carefully examine the 12 new wells (all of which will all be completed several feet into the ground water) to determine if any free product exists within the vicinity of Pumphouse #2. Bail-down tests will be performed at any well containing free product to determine the rate of product recovery that may be feasible at this site.

4.3.3 Biosparging Test *Not yet.*

Biosparging involves the injection of air into saturated soils with the purpose of increasing DO levels and removing a portion of the BTEX from the source area ground water through volatilization. Biosparging is under consideration at this site because initial measurements indicate that less than 2 ppm of DO is available throughout most of the source area.

A single sparging point will be established near the northern corner of the fenced area at Pumphouse #2 to measure the potential upgradient and downgradient impact of air injection on ground water DO concentrations. The sparging point will be constructed of 1-inch, Schedule 80 PVC with a 2-foot screened interval placed at a depth of 6 to 8 feet bgs. An oilless, rotary-vane compressor will be used to inject air at an estimated 3 to 5 standard cubic feet per minute (scfm) into the shallow aquifer. The required injection pressures will be measured for various flow rates. Initial and daily DO readings will be made at a newly installed well near the sparging point and at MW-18 to estimate the radius of oxygen influence from a single sparging point. Data from this test will be used in the event that a larger biosparging system is required to provide additional oxygen to the shallow aquifer to promote more rapid biodegradation of BTEX compounds.

SECTION 5

REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of the field work in support of the risk-based approach, a quantitative source and release analysis using simple partitioning models and Bioplume II will be completed to determine the fate and transport of fuel-hydrocarbon contamination at the site and to estimate the effectiveness of intrinsic remediation. For example, the Bioplume II model will be used to investigate whether natural attenuation is occurring at the site, and if so, to what extent this process is minimizing contaminant migration. Based upon model predictions of contaminant concentrations and distributions in various media through time, an exposure pathway assessment will be conducted. If the model predictions suggest that contamination may exist at or migrate to an exposure point, the exposure pathway will be considered complete. To identify the type and magnitude of remediation that may be required to protect human health and the environment, appropriate numerical remediation goals for each environmental medium and COC that are protective of human health and the environment will be identified. Data from the models used to determine whether an exposure pathway may be complete will also be used to estimate exposure-point concentrations using the guidance developed by EPA (1992b) concerning reasonable maximum exposure concentrations.

A qualitative screening of the various remedial technologies will be conducted to narrow the list to only those that are likely to address the principal threats posed by the site. These remedial technologies will then be combined as necessary to create a remedial alternative (e.g., alternative 1: bioventing, intrinsic remediation, long-term monitoring, and deed restriction recordation). An iterative, quantitative evaluation of the effectiveness of these final remedial alternatives in achieving these site-specific remediation goals will then be completed.

5.1 EE/CA OBJECTIVES

what test?
The objectives of this field test and the EE/CA are to evaluate, select, design, and implement the remedial alternative that:

- Meets the cleanup goals for the site,
- Is permanent or achieves the highest degree of long-term effectiveness possible, and
- Is cost effective in that it achieves the best balance between long-term effectiveness and cost.

The EE/CA report prepared as part of this project will also provide a quantitative estimate of any risks posed by existing contamination as well as risks posed by residual contamination after implementation of the remedial option. The EE/CA report will contain complete information on

all aspects of the final remedial alternative recommended for the site, including quantitative and other evaluation data, long-term monitoring requirements, and any long-term land use restrictions.

5.2 MAJOR COMPONENTS OF THE EE/CA

The following sections briefly present the major components of an EE/CA. The EE/CA report will contain detailed information on field and laboratory analytical results; quantitative source, release, fate, and transport analyses; exposure-point concentrations; receptors; toxicity data; risk characterization information; identification of appropriate remediation goals; and the factors affecting and methods used to evaluate potential remedial alternatives for the site. The EE/CA report will also recommend and present a design for the most appropriate remedial alternative for the site. Construction of required source removal systems will begin immediately following base and regulatory approval of the EE/CA report.

5.2.1 Data Presentation

The EE/CA report will be structured to clearly and concisely present the approach and results of each of the major steps completed to select, design, and implement an appropriate remedial alternative for the site which minimizes risks to human health and the environment to the extent practical. Figure 5.1 presents an example EE/CA report outline that will guide the development of data and supporting text. The EE/CA report will be structured to place emphasis on the results of field work, risk analysis, and remedial alternative evaluation. Detailed information on the methodologies used in each of these steps will be contained in appendices to the EE/CA report. This approach should streamline the final report to focus on the results of the evaluation. In this way, regulators and other decision-makers will not have excessive documentation to review to determine whether the recommended remedial alternative meets the stated objectives of the project.

5.2.2 Data Evaluation and Modeling

Data from field work conducted in support of the risk-based remediation project that will be used in quantitative analyses will be gathered and sorted by environmental medium. Any analytical data used in this demonstration project will be evaluated in terms of their quality. This data usability review will include a review of the analytical methods, quantitation limits, and other factors important in determining the precision, accuracy, completeness, and representativeness of the final data set. The outcome of this data evaluation will be a data set appropriate to support quantitative fate and transport analyses and risk analysis. The data evaluation methods defined by EPA (1989b) in OSWER Directive 9285.7-01a, *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual* (EPA/540/1-89/002), and OSWER Directive 9285.7-09a, *Guidance for Data Usability in Risk Assessment* (EPA, 1992a) will be used as appropriate. By using the analytical methods and quantitation limits defined in this work plan (see Table 4.1), the data collected during the field work phase of this demonstration project are designed to satisfy the rigorous data requirements of quantitative fate and transport modeling and risk analysis.

Results of the data evaluation will be summarized in the EE/CA report. Data will be used as input parameters to the various quantitative models discussed in Section 3.2 and 3.3 and, as

FIGURE 5.1

**EXAMPLE EE/CA REPORT OUTLINE
RISK-BASED APPROACH TO REMEDIATION
PUMPHOUSE #2, MALMSTROM AFB, MONTANA**

Executive Summary

- 1.0 Introduction
 - 1.1 Purpose and Scope
 - 1.2 Site Background
 - 1.3 Report Organization
- 2.0 Site Description
 - 2.1 Physical Setting
 - 2.2 Nature and Extent of Contamination
 - 2.2.1 Previous Investigations
 - 2.2.2 Recent Data
 - 2.3 Indicator Analyte Data
 - 2.4 Discussion of Evidence of Intrinsic Remediation
- 3.0 Evaluation Methods and Criteria
 - 3.1 Remedial Action Objectives
 - 3.2 Potential Exposure Pathways for Human/Ecological Receptors
 - 3.3 Site-Specific Fate and Transport Models
 - 3.4 Site-Specific Cleanup Goals
 - 3.5 Review of Evaluation Criteria
 - 3.5.1 Protectiveness
 - 3.5.2 Implementability
 - 3.5.3 Cost
- 4.0 General Description of Potential Remedial Alternatives (Examples)
 - 4.1 Alternative 1: Intrinsic Remediation/Long-term Monitoring
 - 4.2 Alternative 2: Bioventing to Remove Soil Source(s)/Intrinsic Remediation/Long-Term Monitoring
 - 4.3 Alternative 3: Remove Free Product/Intrinsic Remediation/Long-Term Monitoring
 - 4.4 Alternative 4: Soil Vapor Extraction/Ground Water Pump and Treat
- 5.0 Comparative Analysis of Remedial Alternatives
 - 5.1 Protectiveness
 - 5.2 Implementability
 - 5.2.1 Technical
 - 5.2.2 Administrative
 - 5.3 Cost
 - 5.3.1 Capital Costs
 - 5.3.2 Operating Costs
 - 5.3.3 Present Worth Cost
- 6.0 Recommended Remedial Alternative
- 7.0 References

Appendix A: Data Evaluation for Risk Analysis

Appendix B: Development of Site-Specific Cleanup Goals

Appendix C: Quantitative Exposure Assessment Data (Model Simulations)

necessary, to explore potential exposure pathways that may or will be completed at the site. Models which require a single-point concentration value (e.g., air dispersion) will use exposure-point concentrations developed using the EPA (1992b) *Supplemental Guidance to RAGS: Calculating the Concentration Term* (Publication 9285.7-081). This guidance is designed to assist in the development of an exposure concentration that represents the highest exposure that could reasonably be expected to occur for a given reasonable maximum exposure duration. This value is intended to account for both the uncertainty in environmental data and the variability in exposure parameters.

More complex models such as Bioplume II do not require single-point values. In these cases, unadjusted field data will be used to simulate the fate and transport of contamination in the ground water. If model predictions demonstrate that an exposure pathway involving ground water is not complete, it will be unnecessary to develop exposure-point concentrations to compare to appropriate cleanup goals. Conversely, if model predictions show that an exposure pathway involving ground water is or may be completed, data from model sensitivity runs at the point of exposure will be statistically evaluated to determine a single-point exposure concentration. The goal of this approach is to factor model uncertainty into the development of an exposure-point concentration that is most representative of the reasonable maximum exposure at the site. Again, EPA (1992b) guidance will be followed to develop exposure concentration values suitable for comparison to appropriate cleanup concentration goals.

5.2.3 Method of Risk Analysis

The risk-based approach to remediation improves upon traditional approaches by using the tools of risk assessment to identify the remedial alternative that best balances risk reduction and remediation costs. The risk analysis to be completed in support of this project encompasses the four basic components of a traditional risk assessment: data evaluation, exposure assessment, toxicity assessment, and risk characterization. These components will be used to evaluate the long-term risks associated with the various remedial alternatives that could be used at a site (hence the name, risk-based approach). The risk analysis will then be used to identify which remedial alternative best addresses site-specific risks. The methods of risk analysis employed will be generally consistent with the risk assessment methods described in RAGS, Volume I (EPA, 1989b) and analogous to those used to evaluate long-term risks associated with various remedial alternatives. Figure 5.2 summarizes the risk analysis method.

5.2.3.1 Exposure Pathway Evaluation

As described in Section 3, an exposure assessment identifies the potential human and ecological receptors that could come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a mechanism of release, a receptor, and a route through which the contamination could reach the receptor. The risk-based approach to remediation is designed to use quantitative field data and models to characterize both the existing nature and extent of contamination and what effect various remedial technologies such as

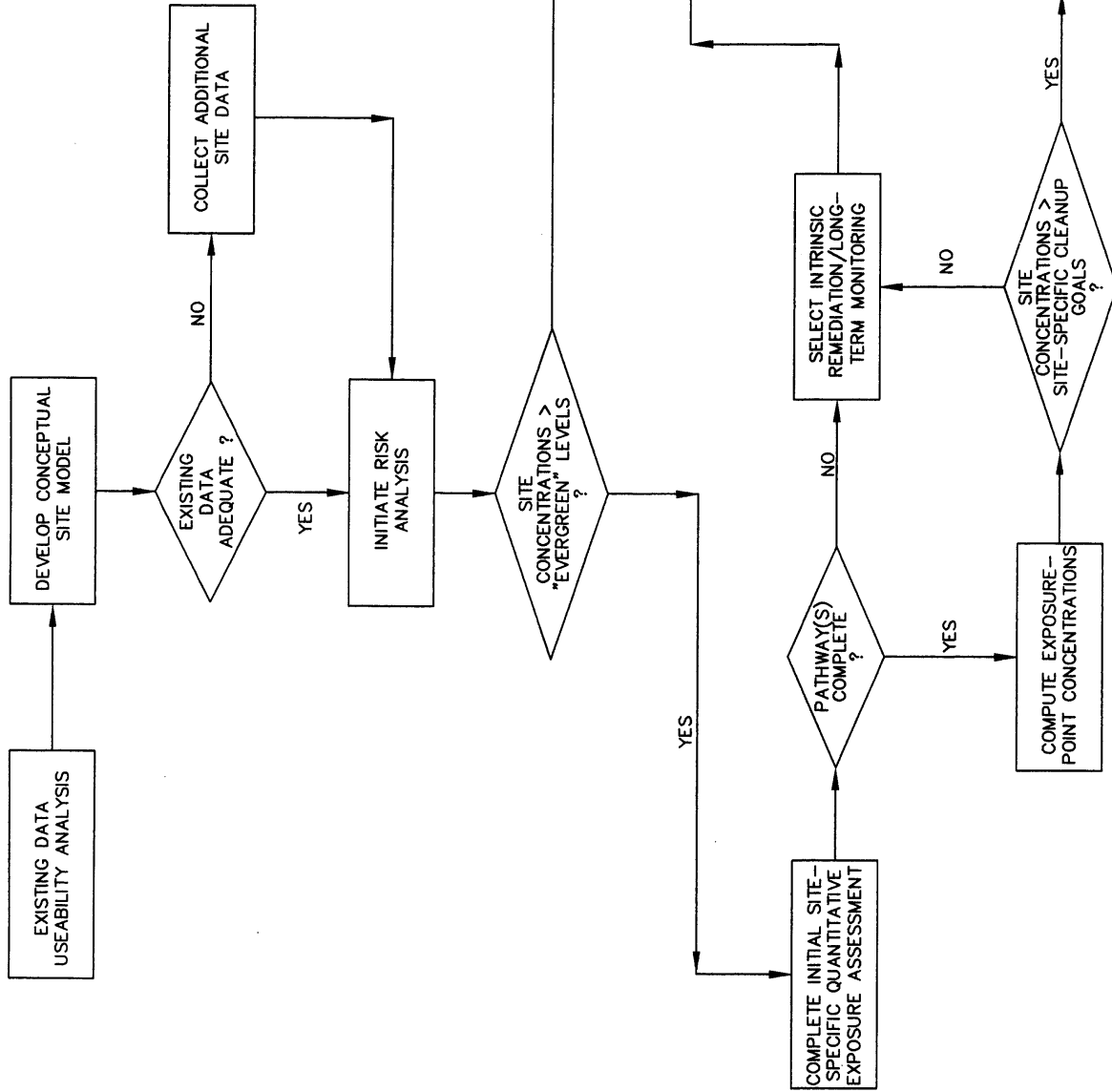


FIGURE 5.2

RISK ANALYSIS METHOD

EE/CA Work Plan
Risk-Based Approach to Remediation
Pumphouse #2, Malmstrom AFB, Montana

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intrinsic remediation will have on the fate and transport of contaminants in the environment through time. The CSM presented in Section 3 of this work plan identifies potential sources and release mechanisms, current and potential future receptors, exposure points, and exposure routes that may be involved in current or future land-use scenarios for the site. This CSM was developed to ensure that adequate data are collected to support a quantitative evaluation of the potential for exposure pathway completion at the site.

Field data and model simulations which account for the physical setting and characteristics of the site will be used to estimate whether any exposure pathway is completed and, if so, to quantify the COC concentrations at the point of exposure. The method of risk analysis to be used as part of this demonstration project hinges on achieving site-specific remediation goals for each affected environmental medium.

If an exposure pathway is determined to be completed, the exposure assessment will be expanded to calculate exposure point concentrations. As discussed in Section 5.2.2, field data and model simulation results will be statistically evaluated using EPA (1992b) guidance on how to calculate a single-point concentration level that represents the highest concentration to which a receptor could reasonably be exposed given site conditions. Using modeled data in the calculation of the exposure-point concentration is designed to account for the positive effects of natural attenuation processes that may be operating at the site.

5.2.3.2 Identifying Cleanup Goals

To evaluate, select, and design an appropriate remedial alternative for the site, long-term target remediation goals must be defined. Achievement of these remediation goals should result in residual contaminant levels that are protective of human health and the environment. Use of these cleanup goals to screen remedial technologies early in the process will streamline the decision-making process. Chemical-specific cleanup goals for each environmental medium can either be based on promulgated standards such as MCLs or based on site-specific risks. Identification of site-specific criteria depend upon which chemicals are present at the site, which environmental medium are or may become contaminated, land-use assumptions, and exposure assumptions. One of the key objectives of the risk-based approach to remediation is to provide a more flexible and scientifically supportable basis for making remedial decisions. Identifying appropriate cleanup goals for a site depends on site-specific data on probable land use and how potential receptors can and cannot come into contact with site-related contamination.

The sources for toxicity information for human receptors will be limited to IRIS (Micromedix Inc., 1994) and the Health Effects Assessment Summary Tables (HEAST) (EPA, 1994). If toxicity data for ecological receptors is necessary (i.e., an exposure pathway is complete), available guidelines and technical literature will be consulted. No attempt will be made to develop toxicity values from any other sources as part of this project. Any uncertainties associated with developing remediation goals will be identified and discussed in the EE/CA. The potential impact of these uncertainties on the development of appropriate remediation goals will also be qualitatively evaluated.

The risk-based approach to remediation provides a more flexible and scientifically supportable basis for making remedial decisions. Identifying appropriate cleanup goals for a site depends on

site-specific data on probable land use and how potential receptors can and cannot come into contact with site-related contamination.

5.2.3.2.1 Air

Determination of air cleanup goals for a site depends on the current and probable land use of the area. For areas downwind of Pumphouse #2 which are used or may be available for residential use, air concentrations will not exceed an excess upperbound lifetime cancer risk of between one in 10,000 (10^{-4}) and one in 1,000,000 (10^{-6}) for known or suspected carcinogens. Air concentrations of any COCs which are systemic toxicants will not present an appreciable risk of deleterious effect during a lifetime or part of a lifetime. Nonsystemic toxicant effects are factored into risk-based cleanup goals through the use of a hazard index. A hazard index is the sum of all hazard quotients for a single or multiple systemic toxicants which affect the same target organ or act by the same method of toxicity. A hazard index of 1 or less indicates that no appreciable noncarcinogenic risk due to inhalation exists. For areas that are demonstrated to be unavailable for uncontrolled use (e.g., through institution controls), concentrations of contaminants in air (either during or after remediation) will not exceed either Occupational Safety and Health Administration (OSHA) permissible exposure limits, threshold limit values, or other criteria applicable to an industrial exposure setting.

5.2.3.2.2 Soil

Risk-based remediation goals may be the only human health comparison criteria appropriate for soil at the site, as no appropriate promulgated standards may exist. Human health risk-based remediation goals can be developed for all COCs by setting the carcinogenic target risk level at 10^{-6} and the hazard index at 1 for each group of the systemic toxicants which affect the same target organ or act by the same method of toxicity (EPA, 1991a).

Human health risk-based remediation goals for soil will be calculated using standard exposure assumptions appropriate for the exposure scenarios most representative of both current and potential future site conditions. The industrial land-use assumption will be used for sources areas within and areas immediately downgradient of Pumphouse #2. The exposure pathways that are most likely to be incorporated into the soil remediation goals for the COCs include incidental ingestion of soil, inhalation of dust particulates, and inhalation of volatilizing COCs. In this way, the potential for cross-media contamination of air is included in the development of cleanup goals for soils. Standard default exposure variables recommended by EPA (1991d) will be used to develop risk-based soil cleanup goals.

Cross-media contamination of ground water from contaminated soil will also be factored into the development of soil cleanup goals to ensure that soil is remediated to a level protective of downgradient ground water quality. Soil cleanup goals will also be determined to protect air quality. Fate and transport models, such as the Summers model and the air dispersion model discussed in Section 3.3, may be incorporated into this analysis to ensure that the selected remedial alternative minimizes cross-media contamination.

Chemical-specific concentration goals for soils that are protective of potential ecological receptors can be estimated by using chemical-specific ecological comparison criteria such as certain toxicological values documented in the scientific literature intended to be environmentally protective. As noted earlier, however, there are few or no toxicological data for the COCs for

terrestrial plants and animals. Although these contaminants may be bioavailable for uptake by plants and/or animals, VOCs generally do not bioaccumulate in tissues or biomagnify through the food web. However, available data will be screened to identify potential ecological comparison criteria for any potential ecological receptors. Observed or modeled concentrations at the point of exposure in the environmental media of concern (e.g., soil) will then be compared to available comparison criteria. If contaminant concentrations meet or exceed available comparison criteria designed to be protective of ecological receptors, quantitative data will be used to determine the type and magnitude of remediation necessary to minimize risks. As noted previously, however, there are likely to be no completed exposure pathways to ecological receptors involving soil.

5.2.3.2.3 Ground Water

Chemical-specific concentration goals for ground water can also be risk-based or based on promulgated standards, whichever are most appropriate for the site. Federal water quality and state drinking water standards are common promulgated remediation goals used to set ground water concentration goals. In addition, other types of laws, such as state antidegradation laws, may drive development of ground water remediation goals if they are accompanied by allowable concentrations of a chemical (i.e., qualitative direction is not equivalent to quantitative standards).

However, the shallow ground water underlying Pumphouse #2 is not currently used to meet potable water demands. Further, given the location of Pumphouse #2 on Malmstrom AFB and the characteristics of this perched aquifer, shallow ground water within the industrial source area and immediately downgradient of the site is not likely to be available for uncontrolled use in the future. Ground water underlying the source area and immediately downgradient of the site should not be classified as having beneficial use as a drinking water supply, suitable for human consumption, due to the land use restrictions imposed by site location and other institutional controls deemed necessary to prevent uncontrolled use of natural ground water resources on-base. Additionally, the hydrogeologic evidence at Pumphouse #2 suggests that this aquifer could not yield an adequate water source for even a small residence. Risk-based ground water cleanup goals will be developed to reflect site-specific conditions using the procedures described in EPA (1991a) OSWER Directive 9285.7-01B entitled *Human Health Evaluation Manual, Part B: Development of Risk-based Preliminary Remediation Goals*. EPA Directive 9481.00-6C will also be useful in developing risk-based ground water cleanup goals that ensure that the contaminant plume does not increase in size or concentration above allowable environmental exposure levels.

Ground water downgradient from this area will be designated as having potential future beneficial use as a drinking water supply. Point-of-compliance (POC) wells will be installed to monitor ground water quality over time at the furthest upgradient point where no controls on activities will be maintained. Ground water quality at and downgradient of the POC will not degrade beyond concentrations determined to be protective of human health and the environment assuming uncontrolled use as a direct result of Pumphouse #2 activities. The remediation approach for Pumphouse #2 will be sufficient to protect downgradient ground water resources in hydrologic communication with ground water underlying source areas within and immediately downgradient of Pumphouse #2.

Section 3 of this work plan presents a more detailed discussion of probable land use at and downgradient of the site. This project will provide sufficient data to demonstrate that proposed

ground water remediation goals, which may be area-specific, are consistent with the letter and intent of guidance on ground water concentration goals. All ground water remediation goals will also account for technology limitations.

5.2.3.2.4 Surface Water

It is possible that surface water standards may also govern the development of ground water concentration goals for Pumphouse #2 if the ground water migrates to and discharges into drainage ditches. However, as described in Section 2.3.4, it is not likely that ground water will impact any surface water bodies downgradient of the site. This exposure pathway will be investigated as part of the field work phase to determine whether this pathway can be considered incomplete. Section 4 of this work plan describes what data will be gathered at the site to support this determination. If the exposure pathway is incomplete, development of cleanup goals that are protective of surface water resources will not be necessary.

5.2.3.3 Risk Determination

The goal of this project is not to determine whether remedial action is warranted at the site, but rather to determine the type and magnitude of remedial action required to minimize risks to human health and the environment to the maximum extent practicable. The potential risks to human and ecological receptors will be determined by comparing the calculated exposure concentrations derived from quantitative fate and transport analyses to the cleanup goals identified to be protective of human health and the environment. If this comparison indicates that natural attenuation of site COCs is occurring and is sufficient to reduce the potential risks to human health and the environment, ES may recommend implementation of natural attenuation with long-term monitoring as the preferred remedial alternative. The EE/CA report prepared to demonstrate the effectiveness of the intrinsic remediation could be adapted to supplement a corrective measures study (CMS) for the site.

5.2.4 Evaluation of Source Removal/Risk Reduction Options

To provide adequate data and analyses in support of the selection, design, and implementation of an appropriate remedial alternative for Pumphouse #2, it will be necessary to critically evaluate single or combined remedial technologies in terms of long-term effectiveness, implementability, and cost. Field data, quantitative fate and transport modeling designed to explore the potential effectiveness of natural attenuation processes, and several other institutional and engineering technologies will be evaluated for their risk reduction potential. Combinations of institutional controls and cost-effective site remediation methods will be evaluated following the EE/CA process described in this section. Based on guidance from AFCEE, a minimum of three options will be evaluated for a site. Each option will be evaluated against three primary criteria: effectiveness in protecting human health and the environment, implementability, and cost.

Effectiveness - Each remedial alternative will be analyzed to determine how effectively it will protect both current and future receptors from potential risks associated with COCs. This analysis will be based on determining whether the remedial alternative can achieve and maintain final cleanup goals. Effectiveness will also include permanence and ability to reduce contaminant mass, volume, and toxicity. Section 5.2.3 provides a more detailed description of the risk methods that will be used to determine the effectiveness of protection.

Implementability - The technical implementation of each remedial option will be evaluated. The expected technical effectiveness of each remedial alternative will be described. Potential shortcomings and difficulties in construction, operations, and monitoring will be presented and weighed against perceived benefits. The administrative implementation (regulatory and community acceptance) of each remedial approach also will be discussed. This is an important element of the EE/CA, particularly when intrinsic remediation is determined to be the most cost-effective method of risk reduction.

Cost - The estimated cost of each remedial option will be presented. Both capital and operating costs will be estimated along with a present-worth cost estimate for the predicted operating life of each option. Cost assumptions will be clearly stated, and the cost sensitivity of assumptions will be discussed.

It is important to note, however, that the most effective remedial technology or remedial alternative may not be the most cost-effective option for the site. Because the objective of this project is to identify, design, and implement the most cost-effective remedial alternative at Pumphouse #2, it will be necessary to apply the test of cost effectiveness. A cost-effective remedial alternative is one that achieves the best balance between long-term effectiveness and cost of all the remedial alternatives which meet the cleanup objectives for the site. The test of cost effectiveness may be more extensive for a range of remedial alternatives which vary only in degree of long-term effectiveness, but which will all achieve the site cleanup goals. The remedial alternative which achieves the site cleanup goals at the lowest cost will be identified. The total cost for the other remedial alternatives will also be estimated, and all remedial alternatives will be ranked according to their degree of long-term effectiveness. The remedial alternative that provides the best balance between long-term effectiveness and cost would be the most cost effective.

The following sections describe the remedial options that will, at a minimum, be considered for Pumphouse #2 in accordance with the statement of work (SOW) and subsequent AFCEE project direction.

5.2.4.1 Intrinsic Remediation Only with Long-Term Monitoring

Fate and transport models described in Section 3.2 and 3.3 will be used to estimate the natural reduction of contaminants of concern due to biodegradation, adsorption, and dilution. The ability of this remedial option to naturally reduce risk under the scrutiny of long-term monitoring will be described. If sufficient risk reduction cannot be achieved through intrinsic remediation alone, the potential for unacceptable risk will be discussed along with institutional controls which could be implemented to eliminate or reduce contact between the COCs and any at-risk receptors.

5.2.4.2 Limited Source Removal

If the intrinsic remediation option does not provide adequate protection of human health or the environment, additional removal of the contaminant source will be required. Even if intrinsic remediation appears to be protective, the uncertainties of fate and transport models may necessitate that some level of active remediation be completed to reduce uncertainties associated with the long-term source of contamination. In these situations, the value of low-cost source removal technologies such as bioventing, free product removal, or biosparging will be evaluated. The selection of an appropriate source removal action will begin with a review of the site cleanup

goals for soil and ground water. Using these cleanup goals, it will be possible to estimate the amount of additional source removal required to minimize risks to potential receptors and to protect environmental resources. In the case of downgradient ground water contamination, the Bioplume II data set will be modified to include the reduced source concentrations anticipated from the remedial option. The resulting reductions in soil and downgradient plume concentrations will then be compared against site-specific cleanup goals. Source removal will be increased until predicted concentrations are significantly less than the cleanup goals. In some cases, two or more source removal technologies will be integrated in this option.

5.2.4.3 Intensive Source Removal and Ground Water Pumping

Immediate reductions in contamination can be achieved through more intensive source removal options such as soil vapor extraction and the extraction and treatment of contaminated ground water. Although this intensity of treatment may not be required based on the current or future risks posed by site contaminants, AFCEE has requested that the benefits and additional costs of intensive treatment be evaluated during the EE/CA.

5.2.5 Selection of a Recommended Approach

Based on an evaluation of the protectiveness, implementability, and cost of each option, ES will recommend the option which provides the greatest protection for the lowest cost. If remediation of the source area is recommended, a conceptual design of the remediation system will be prepared and included in the EE/CA report for Air Force and regulatory review. If intrinsic remediation is an integral part of the recommended option, a long-term monitoring plan will be developed to ensure both soil and ground water contamination are decreasing according to the remediation strategy.

5.2.6 Long-Term Monitoring Plan

Upon completion of the field work phase of this project, quantitative fate and transport models will be coupled with the CSM to complete an exposure assessment for the site. As described in this work plan, a tiered approach will be used to assess the potential effectiveness of various remedial alternatives at reducing or eliminating risks to potential receptors. If this analysis indicates that intrinsic remediation is sufficient to reduce the potential risk to human health and the environment, the most cost-effective remedial alternative for the site will be intrinsic remediation and long-term monitoring. A site-specific, long-term monitoring plan will be included as part of the EE/CA which specifies the location of confirmation, POC, and other monitoring wells and the sampling frequencies necessary to demonstrate long-term effectiveness and permanence of the selected remedial alternative. ✓

Confirmation wells will be located immediately downgradient (i.e., within 1 or 2 years) of the existing plume and will provide for early confirmation of model and engineering predictions. The POC wells will be located further downgradient (e.g., along the property boundary; approximately 5 years downgradient of the existing plume; 1 or 2 years upgradient of the nearest potential receptor of ground water contamination). The exact location of POC wells will be established in concert with regulatory authorities to be protective of any potential receptor. The long-term monitoring plan will specify which existing wells will be used to monitor the effectiveness of intrinsic remediation processes at the site. At a minimum, the wells to be included in the long-term monitoring plan will be located upgradient of the source area, within the anaerobic treatment

zone, and within the aerobic treatment zone. Confirmation and POC wells will also be included in the network of long-term monitoring wells for the site. The sampling frequency of the well network will depend on their exact location, risk reduction needs, and other regulatory considerations.

If quantitative data analysis indicates that intrinsic remediation will be insufficient alone to minimize receptor risks, other innovative source removal technologies such as bioventing or biosparging will be evaluated. The reduction of source and dissolved COCs should result from additional remedial activities will be used in the quantitative fate and transport analyses for the site. Thus the models will be used to predict exposure pathway completion and exposure-point concentrations resulting from supplementing intrinsic remediation with other source removal technologies. Again, once the most cost-effective remedial alternative is identified, the EE/CA report will include a long-term monitoring plan which will contain any recommended plans for extended tests and sampling required to demonstrate the anticipated long-term effectiveness and permanence of the selected remedial alternative. ✓

Following the implementation of any required source removal technologies at the site, ES will operate the source removal system for a total of 600 days. At the end of the 600 days of treatment, ES will return to the site and resample soils in the source area to determine the degree of COC removal and evaluate the potential impact of source removal on the long-term fate and transport of dissolved or vapor phase contamination. A letter report will be prepared outlining the interim source removal results and the potential impact on the ground water plume, and making recommendations for continued source removal if required. ?

5.3 REGULATORY COORDINATION STRATEGY

The risk-based approach described in this work plan conforms to both EPA risk assessment guidance and verbal guidance received from representatives from the State of Montana Department of Health and Environmental Sciences. On 9 June 1994, an initial coordination meeting was held at the civil engineering offices on Malmstrom AFB to describe, and obtain general concurrence with, the risk-based approach for Pumphouse #2. Representatives from AFCEE, Malmstrom AFB, EPA, the State of Montana Department of Health and Environmental Sciences, and ES were present. The general approach was approved. Following AFCEE and base review of this work plan, an informational copy will be forwarded to Mr. Richard Knatterud of the State of Montana Department of Health and Environmental Sciences and Ms. Rosemary Rowe of EPA, Region VIII.

The EE/CA report will serve as the primary document for obtaining regulatory approval for the risk-based remediation approach. This document will contain all of the supporting data to satisfy the requirements of relevant EPA (1989-1993) risk assessment guidance material, and will provide sufficient evidence to state regulatory authorities to support the selection of the recommended remedial alternative. The EE/CA report will provide quantitative evidence of intrinsic remediation and develop final cleanup goals for each affected medium based on risk criteria. If source removal is required, the EE/CA report will provide a conceptual design that is sufficient in detail to gain regulatory approval to proceed with the remediation. A long-term monitoring plan will be provided to ensure that the predictions of fate and transport modeling can be verified and that COCs do not migrate at concentrations which could cause an unacceptable

risk to human or ecological receptors. Confirmation and POC wells will be established to verify that intrinsic remediation is occurring and that plume migration is limited.

Following AFCEE and base review of the draft EE/CA report, their comments will be incorporated into a final draft for regulatory review and approval. When the final draft is completed, AFCEE and ES will provide a technical presentation to base officials and regulatory agencies to familiarize them with the key findings and recommendations of the EE/CA report. Copies of the EE/CA report will be provided to regulators at the meeting, and a 30-day review will be requested.

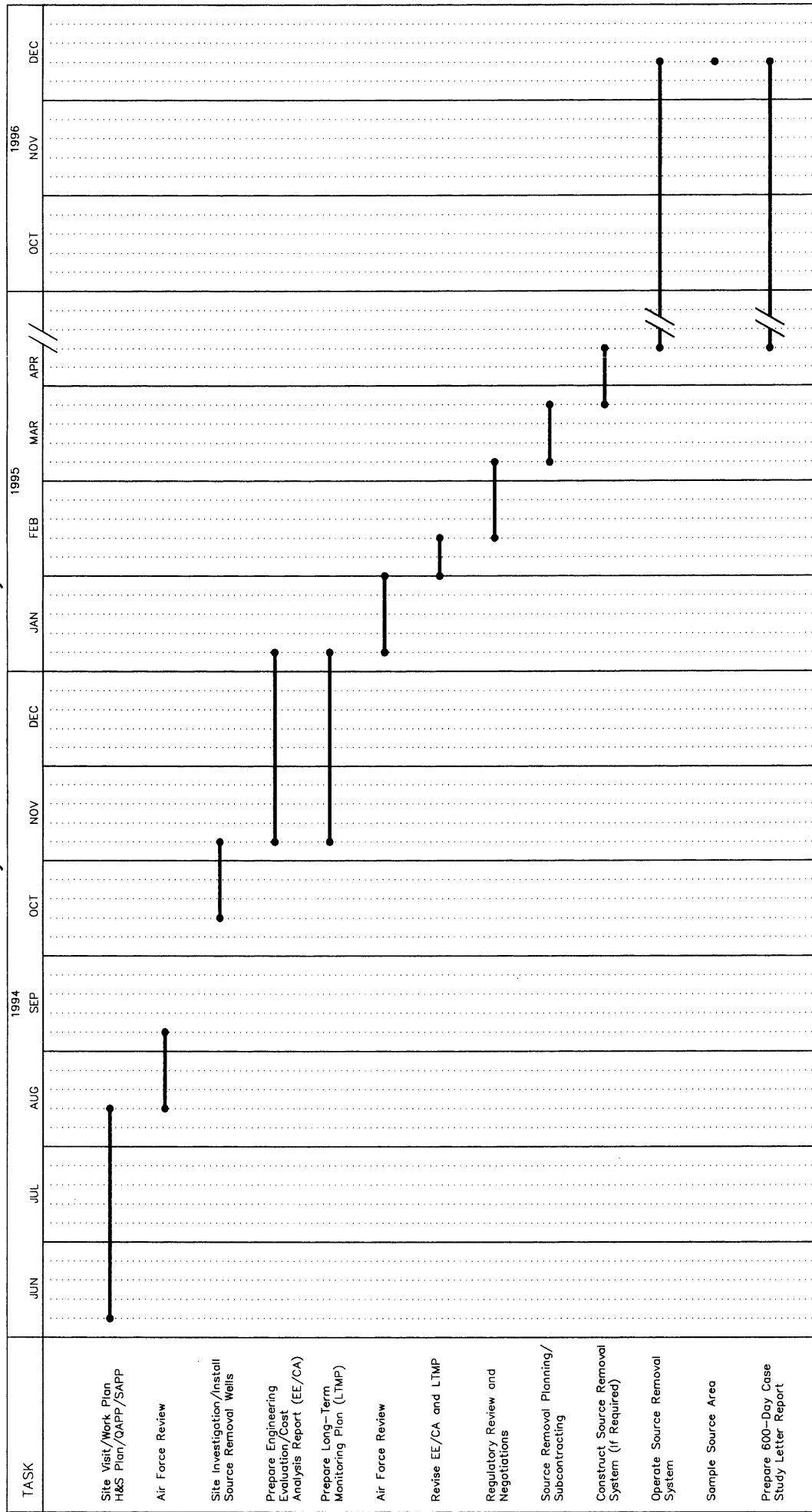
SECTION 6

PROPOSED PROJECT SCHEDULE

The following timeline details the proposed duration of and date of completion for each of the major tasks involved in evaluating, selecting, designing, and implementing a remedial alternative for Pumphouse #2 which minimizes contaminant migration and risks to potential receptors. Each of these major tasks is described in other sections of this work plan.

FIGURE 6.1

RISK-BASED DEMONSTRATION SCHEDULE PUMPHOUSE #2, MALMSTROM AFB, MONTANA



SECTION 7

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SITE SAMPLING AND ANALYSIS PLAN
FOR
RISK-BASED REMEDIATION DEMONSTRATION
AT PUPMHOUSE #2, MALMSTROM AFB, MONTANA

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
TECHNOLOGY TRANSFER DIVISION (ERT)
BROOKS AIR FORCE BASE, TEXAS 78235-5000

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Prepared by:

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900
Denver, Colorado 80290

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The purpose of this site-specific sampling and analysis plan (SAP) is to provide the procedures to be followed when collecting additional data in support of the risk-based approach to remediation at Pumphouse #2. Details on analytical requirements, desired quantitation (detection) limits, and proposed sample locations are identified within section 4 of the work plan. Specific health and safety requirements are described in both the program health and safety (H&S) plan and the site-specific addendum (Appendix B). The need to collect additional samples to meet quality assurance requirements are described in the program quality assurance project plan (QAPP). Specific quality assurance sampling requirements for Pumphouse #2 are summarized herein as part of the site-specific sampling procedures. These additional samples will be used to determine the precision, accuracy, completeness, and representativeness of the final data set.

Soil gas sampling is described in Section 1; soil flux sampling is described in Section 2; drilling, soil sampling, lithologic logging, and bioventing and ground water monitoring well installation procedures are described in Section 3; ground water sampling procedures are described in Section 4; aquifer testing procedures are described in Section 5; surface water sampling procedures are described in Section 6; and field quality assurance/quality control (QA/QC) samples are described in Section 7.

A.1 SOIL GAS SAMPLING

Soil gas will be used as an indicator of subsurface hydrocarbon contamination and to assess the feasibility of using bioventing to remove source contamination at the site. The use of soil gas to delineate potential subsurface contamination and to determine bioventing feasibility has several economic and technical advantages over more traditional drilling and soil sampling techniques. The labor and equipment cost can be significantly less than a conventional drilling and sampling team. Many new hydraulically driven, multi-purpose probes can be used for soil gas sampling. These probes can be advanced as quickly as conventional augers and do not produce drill cuttings which can require expensive analysis and disposal. Further, soil gas sampling can represent the average chemistry of several cubic feet of soil as compared to a discrete soil sample, which can only describe a few cubic inches of the subsurface. This is of particular importance in risk-based remediation projects where the extent of COC contamination and the degree of removal of COCs can most accurately be determined by using multiple soil gas sampling locations.

However, collection of soil gas from very moist soils and particularly fine-grained units can be technically infeasible. Moreover, collection of soil gas samples from low-permeability soils often result in the leakage of atmospheric air into the sampling system and causes inaccurate results. Deep contamination and contamination in tight or cobble soil are still best assessed using standard drilling techniques rather than soil gas probes.

The test equipment and methods that will be required to conduct field soil gas surveys as part of the risk-based remediation at this site are described fully in the AFCEE document *Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential* (AFCEE, 1994). In summary, the soil gas survey will be conducted first at this site to determine the areal extent and possible shallow vertical extent of soil gas and soil contamination. Results from this survey will be used to guide soil drilling, sampling, and well installation. Data from this survey

will also be used to determine if bioventing is a necessary and feasible source removal technique for the site. For example, if the soil gas survey indicates that sufficient oxygen (O₂) is naturally available and distributed throughout the subsurface, bioventing may not be required to enhance fuel biodegradation rates (AFCEE, 1994).

Soil gas sampling will be conducted using small-diameter [approximately 5/8- to 1-inch outside-diameter (OD)] stainless steel probes. The typical probe consists of a drive point with a retractable, perforated tip that is threaded onto a series of drive rod extensions. The soil probe is fitted with a replaceable stainless steel screen to prevent fine-grained soils from clogging the perforations. Before use, 1/8-inch-diameter flexible Tygon™ tubing is connected to the soil probe and passed through the center of the drive rods. The 1/8-inch Tygon™ tubing, which is used to collect the soil gas samples, extends from the soil probe to the purge pump or sampling device at the surface. A new section of Tygon™ tubing will be used for each sampling point.

A digging permit from Malmstrom AFB and utility clearances must be obtained prior to probe use. All necessary digging and drilling permits will be obtained by Malmstrom AFB personnel prior to ES mobilizing to the field. The primary utilities in the investigation area are buried fuel transfer lines, buried water lines, and buried steam transfer lines. Temporary probes utilize either a hand-driven electric hammer or a hydraulic ram. Soil texture and sample depth requirements must be evaluated before determining which probe is best for the site. A hand-driven electric hammer soil gas probe should be sufficient for the conditions and data needs at the Pumphouse #2 area at Malmstrom AFB.

Gaseous concentrations of carbon dioxide and oxygen will be analyzed onsite using an O₂/CO₂ analyzer. The analyzer will generally have an internal battery-powered sampling pump and range settings of 0 to 25 percent for both oxygen and carbon dioxide. Before analyzing samples collected with the soil gas probe, the analyzer must be checked for battery charge level. The analyzer will also be calibrated daily using atmospheric conditions of oxygen (20.9 percent) and carbon dioxide (0.05 percent) and a gas standard containing 0.0 percent oxygen and 5.0 percent carbon dioxide.

Total volatile hydrocarbon (TVH) concentrations will be used as the primary screening tool at this site. The TVH analyzer used at Pumphouse #2 will be capable of measuring hydrocarbon concentrations in the range of 1 to 20,000 parts per million, volume per volume (ppmv). The analyzer must also distinguish between methane and non-methane hydrocarbons. The battery charge level on the TVH analyzer will be checked prior to analysis of each collected soil gas sample. The TVH analyzer will also be calibrated daily using a hexane calibration gas.

All soil gas samples taken during the first-phase of the planned soil gas survey will be collected using 3-liter Tedlar™ bags and vacuum chambers. The soil gas sample will then be analyzed by attaching the O₂/CO₂ and TVH analyzers directly to the Tedlar™ bag. Those sample locations identified for compound-specific analysis will be re-sampled using 3-liter Tedlar™ bags and vacuum chambers. The sample will then be transferred to 1-liter SUMMA™ canisters and shipped to the laboratory for compound-specific analysis using EPA Method TO-3 (see Table 4.1 in the work plan).

Field QA/QC procedures for soil gas will include one sampling equipment blank, use of analyte-appropriate containers, and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly

labeled to indicate sample number, location, matrix (e.g., soil gas), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used.

In order to determine if sampling equipment is free from contamination, a sampling equipment blank will be collected. The sampling equipment blank will be collected by assembling the sampling probe and collecting an ambient air sample in a Tedlar™ bag. The equipment blank will be analyzed in the field using the TVH analyzer. An ambient air reading using the TVH analyzer will be obtained immediately prior to obtaining the reading from the Tedlar™ bag containing the sampling equipment blank. A comparison between the TVH analyzer readings for the ambient air and sampling equipment blank will give an indication if the sampling equipment is free from contamination.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

Soil gas QA/QC sampling for analytical purposes will not include a field duplicate since less than ten samples will be collected. However, the laboratory should also plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested for soil gas (i.e., required only once for soil gas extracted via soil gas probe or obtained via flux chamber).

A.2 SOIL FLUX SAMPLING

Several soil flux tests will be conducted at the site to determine the natural background emissions from the site. The purpose of these flux tests is to estimate potential air quality impacts from COC emissions from contaminated environmental medium. Flux samples will be collected at Pumphouse #2 using the procedures outlined in EPA guidance *Measurement of Gaseous Emissions Rates from Land Surfaces Using a Emission Isolation Flux Chamber* (EPA, 1985). The use of a flux box is the preferred method of measurement of surface emission rates of volatile contaminants. A flux box is used to isolate a known surface area from the ambient air, collect surface emissions, and mix the collected emissions with "sweep" air introduced into the chamber at a known flow rate. Data from the flux box can then be combined with a simple dispersion model (such as those described in section 3.3 of the work plan) to identify potential ambient air contamination impacts.

The detection limits presented in Table 4.1 within the work plan are sufficient for the required sensitivity for the compound-specific analysis using a flux box. Flux sample locations are identified on Figure 4.1 within the work plan. Sample locations have been sited in background, potential source areas, areas overlying potential dissolved-phase ground water contamination, and areas downgradient of suspected soil and ground water contamination. The emission rates will not be averaged on an area basis. Rather the data will be used to characterize potential rates of emission for different areas of the site. This approach will support establishment of site-specific remediation goals that are protective of air quality.

The procedures contained within EPA's protocol document on measuring emission rates (i.e., *Measurement of Gaseous Emission Rates from Land Surfaces using an Emission Isolation Flux Chamber* (EPA/600/8-86/008)) will be followed. In summary, gaseous emissions will be collected from an isolated surface area using a flux chamber and monitored using both "real-

time" and discrete methods. Real-time measurements will be made with a portable hydrocarbon analyzer to determine when the chamber reaches steady-state conditions. Discrete samples will then be collected for chemical analysis.

To reduce the potential for cross-contamination, which can occur whenever high level or low level samples are sequentially analyzed, the flux chamber will be purged and tested with a blank after each sample is conducted. Emission tests will only be conducted when soil moisture levels are normal. Increased ground moisture as a result of rain or heavy dew can bias (lower) emission rates.

The sweep air to be used will be dry, organic free air equal to or better than commercial ultra high purity grade (< 0.1 ppmv total hydrocarbon content). Discrete samples will be collected in SUMMA™ canisters and analyzed using EPA Method TO-3 to identify BTEX concentrations.

Field QA/QC procedures for soil flux sample will be identical to those required for soil gas. QA/QC requirements include use of analyte-appropriate containers, and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., soil gas), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

Soil flux QA/QC sampling will not include a field duplicate since less than ten samples will be collected. However, the laboratory should also plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested for soil gas (i.e., required only once for soil gas extracted via soil gas probe or obtained via flux chamber).

A.3 DRILLING, SOIL SAMPLING, AND BIOVENTING AND GROUND WATER MONITORING WELL INSTALLATION

To further characterize the hydrogeologic conditions of the shallow soil and ground water for quantitative fate and transport analyses using the Bioplume II® model, up to 12 new wells will be installed at Pumphouse #2. The following sections describe the proposed well locations and completion intervals, equipment decontamination procedures, drilling and soil sampling, well installation, well development procedures, and well location and datum surveying. All drilling, soil sampling, and well installation will proceed from areas suspected to be least contaminated to areas suspected to be more contaminated.

A.3.1 Well Locations and Completion Intervals

Approximately 12 new wells will be installed to further characterize soil and ground water quality at the site, and support source removal activities if necessary. These wells will be screened from 1 foot above the ground water table to the well completion depth. Appropriate screen intervals will be placed in all new wells depending on their intended purpose. Depths to ground water in the shallow aquifer range from 2.75 to 4.5 feet bgs. Well completion depths are expected to range between approximately 10 and 15 feet bgs. The new well locations were

selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II® model and to support source removal activities as necessary. Figure 4.2 in the body of the work plan shows the proposed well locations.

A.3.2 Drilling and Soil Sampling Procedures

This subsection addresses the procedures for drilling soil borings that will be used for soil sampling and completed as new wells. All new monitoring wells will be installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (EPA, 1987).

A.3.2.1 Pre-Drilling Activities

All necessary digging, drilling, and well installation permits will be obtained by Malmstrom AFB personnel prior to ES mobilizing to the field. In addition, all utility lines will be located and proposed drilling locations cleared prior to any drilling activities.

A.3.2.2 Equipment Decontamination Procedures

Water to be used in drilling, equipment cleaning, or grouting will be obtained from one of the base's onsite water supplies. Malmstrom AFB personnel will assist ES field personnel in locating a suitable source. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for the activities listed above. A decontamination water blank will be collected from the potable water source. The procedures for the collection of the decontamination water blank will be described in Section A.7. The ES field hydrogeologist will make the final determination as to the suitability of site water for these activities.

Prior to arriving at the site, and between each drilling site, the drill rig, augers, drilling rods, bits, casing, samplers, tools and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination.

During drilling operations, the drill rig, augers, and any down-hole drilling and/or sampling equipment will be decontaminated at a temporary decontamination pad that will be set up at the Pumphouse #2 area. The temporary decontamination pad will be constructed in a manner so as to contain all decontamination fluids. All decontamination fluids generated at the temporary decontamination pad will be placed in 55-gallon drums. The decontamination fluids will be disposed of following the procedures presented in Section A.3.5.

All sampling tools will be cleaned onsite, prior to use and between each sampling event, with a clean water/phosphate-free detergent mix and a clean water rinse. All well completion materials that are not factory sealed will be cleaned onsite prior to use with a high-pressure, steam/hot water wash using approved water. Materials that cannot be cleaned to the satisfaction of the ES field hydrogeologist will not be used. All decontamination activities will be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

If contaminated soils are encountered during drilling (based on visual, olfactory, or volatile organic analyzer indications), and the potential for cross-contamination is anticipated, drilling will be stopped and modified drilling procedures will be implemented to prevent the transfer of contaminants to deeper strata.

Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials will not be stored near or in areas which could be affected by these substances. The drill rigs will not be allowed onsite unless they are free from leaks in ~~any~~ hydraulic lines, and are free of ~~any~~ exterior oil and grease.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled drilling fluid will not be allowed to enter any boring or well either during or after drilling/well construction. To prevent this from happening, starter casing, recirculation tanks, berms around the borehole, and surficial bentonite packs, as appropriate, will be used.

A.3.2.3 Drilling and Soil Sampling

Drilling in unconsolidated soils will be accomplished using hollow-stem augers. The borings will be drilled and continuously sampled to the proposed total depth of the monitoring well. A final borehole diameter of at least 10 inches will be required for the installation of bioventing air injection wells with 4-inch inside-diameter (ID) casing. Auger ID will not be less than 5 inches. For installation of ground water monitoring wells, the auger ID will not be less than 4 inches. Determination of well completion details will be at the discretion of the ES field hydrogeologist. It is likely that most boreholes will be drilled to a final diameter of 10 inches within the suspected source area.

If subsurface conditions are such that the planned drilling technique does not produce acceptable results (e.g. unstable borehole walls or poor soil sample recovery) another technique deemed more appropriate to the type of soils present will be used. Any alternate soil sampling procedure used must be approved by the ES field hydrogeologist and will be appropriate for the subsurface lithologies present at the site.

Continuous soil samples will be obtained using a CME[®] split-barrel continuous sampling device or another similar method judged acceptable by the ES field hydrogeologist. Samples will be collected in 2-foot intervals through the capillary fringe smear zone to below the ground water table. The ES field hydrogeologist will identify which samples from the continuous sampling device will be submitted for chemical analysis. Only soils that exhibit possible contamination will be retained for chemical analysis. One goal of the sampling is to collect at least one sample from the interval exhibiting the most concentrated fuel contamination. Soil samples which may be retained for chemical analysis will be placed in sample containers immediately after the core barrel is opened. A maximum of two soil samples for chemical analysis will be collected per borehole. All soil cores will be evaluated for lithologic characteristics, ~~however~~. All soil samples collected will be removed from the continuous sampler and placed on clean aluminum foil for logging.

Every 2-foot soil sample recovered will be subsampled, composited, and placed in a clean container for PID or similar hydrocarbon vapor analyzer headspace measurements for VOCs. Representative portions of the soil samples collected for the headspace procedure will be quickly transferred to the sample containers, which will be sealed and held for 15 minutes at an ambient temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements will be made by puncturing the container seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. The PID will be calibrated daily to 100 parts per million,

volume per volume of isobutylene. It is anticipated that headspace measurements will be performed on all samples collected during the drilling operations to determine which soil samples will be submitted for chemical analysis. The PID will also be used to monitor the worker breathing zone.

As a check on the quality of field sampling activities (sampling, containerization, shipment, and handling) QA/QC trip blanks, field blanks, equipment rinseate samples, and field duplicates will be sent to the laboratory. QA/QC sampling will include two duplicate for soil samples (i.e., frequency of 10 percent), two rinseate samples (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual cooler sent to the analytical laboratory. The procedures for the collection of field QA/QC samples are discussed below in Section A.7. Laboratory QA/QC procedures will include one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

The ES field hydrogeologist will be responsible for observing all drilling and well installation activities, maintaining a detailed descriptive log of subsurface materials recovered, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure A.1. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Soil or rock description, including: relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations;
- Lithologic contacts: the depth of lithologic contacts and/or significant textural changes will be measured and recorded to the nearest 0.1 foot (1 inch); and
- Determination on whether soil sample will be submitted for chemical analysis or segregated as uncontaminated medium.

A.3.2.4 Minimization and Management of Drilling Residuals

Drilling activities will generate soil cuttings requiring proper handling and, if contaminated, proper disposal. Based on data from previous soil sampling efforts at the site, contamination exists throughout the soil profile. The majority of the cuttings are expected to be contaminated. If clean soils are encountered, care will be taken to segregate them from soils containing fuel residuals. Soils will be screened using a PID or similar hydrocarbon vapor analyzer. This limited drilling event will generate approximately 6 cubic yards of soil. The drilling subcontractor will supply all drums for containerizing soil cuttings. Malmstrom AFB will be responsible for sampling and disposal of all contaminated or potentially contaminated soil cuttings. The drums will be staged and temporarily stored onsite as directed by Malmstrom AFB personnel. ✓

BOREHOLE LOG

SITE NAME AND LOCATION 	DRILLING METHOD:					BORING NO.	
	SAMPLING METHOD:					SHEET OF DRILLING	
						START TIME	FINISH TIME
	WATER LEVEL					DATE	DATE
	TIME						
	DATE					CASING DEPTH	

PILL RIG		SURFACE CONDITIONS
ANGLE	BEARING	

SAMPLE HAMMER TORQUE	FT.-LBS
----------------------	---------

DEPTH IN FEET (ELEVATION)	BLOWS/ AN ON SAMPLER (RECOVERY)	CORES			SOIL DESCRIPTION OR ROCK LITHOLOGY	SYMBOL	ROCK STRUCTURE	SAMPLER AND BIT	CASING TYPE	BLOWS/FOOT ON CASING	TEST RESULTS		
		RUN NO.	NO. AND SIZE OF CORE PIECES	% RECOVERY							ROD	DEPTH IN FEET	FROM

The image shows a vertical grid for a geologic boring log. It consists of 11 vertical columns of varying widths. On the right side, there is a vertical scale with horizontal tick marks, likely representing depth in feet or meters. The grid is currently empty, intended for recording geological data from a boring.

Figure A.1
Geologic Boring Log

Figure A.1
Geologic Boring Log

DRILLING CONTRACT

74

LOGGED BY

DATE _____ CLK'D BY _____

A.3.3 Bioventing Well Installations

The potential for vadose soil contamination will be determined along both sides of Flightline Drive in the vicinity of the fuel transfer lines. If continuous soil coring reveals that the fuel-contaminated interval exceeds 2 feet, that boring will be completed as a bioventing air injection well and later included in a possible full-scale bioventing system for reducing contamination in these source areas.

A.3.4 Ground Water Monitoring Well Installation

Ground water monitoring wells will be installed in each of the 12 soil borings not completed as bioventing wells at Pumphouse #2. It is anticipated that two of the wells will be installed as down gradient point-of-compliance wells. Except where specified, the entire thickness of the shallow aquifer will be screened. Detailed well installation procedures are described in the following paragraphs. A typical well completion diagram is included as Figure A.2.

A.3.4.1 Well Material Decontamination

Well completion materials will be inspected by the ES field hydrogeologist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned with a high-pressure, steam/hot water cleaner using approved water prior to use. Prepackaged sand, bentonite, and Portland[®] cement will be used in well construction, and the bags will be inspected for possible external contamination before use. Materials that cannot be cleaned to the satisfaction of the ES field hydrogeologist will not be used.

A.3.4.2 Well Casing

Upon completion of drilling to the proper boring termination depth, a monitoring well casing will be installed. Well construction details will be noted on a Monitoring Well Installation Record form, as shown in Figure A.3. This information will become part of the permanent field record for the site. Blank well casing will be constructed of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. All well casing sections will be flush-threaded; glued joints will not be used. The casing at each well will be fitted with a threaded bottom plug and a top cap constructed of the same type of material as the well casing. The top cap will be vented to maintain ambient atmospheric pressure within the well casing.

The ES field hydrogeologist will verify and record the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus/casing and borehole wall. All lengths and depths will be measured to the nearest 0.1 foot. ✓

A.3.4.3 Well Screen

Well screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches. The screens will be factory slotted with 0.010-inch openings. Each well will be screened so that seasonal fluctuations of the water table can be measured. The water level in the unconfined aquifer will be allowed to fluctuate within the screened interval. The position of the screen will be selected by the ES field hydrogeologist after consideration is given to the geometry and hydraulic characteristics of the stratum in which the well will be screened.

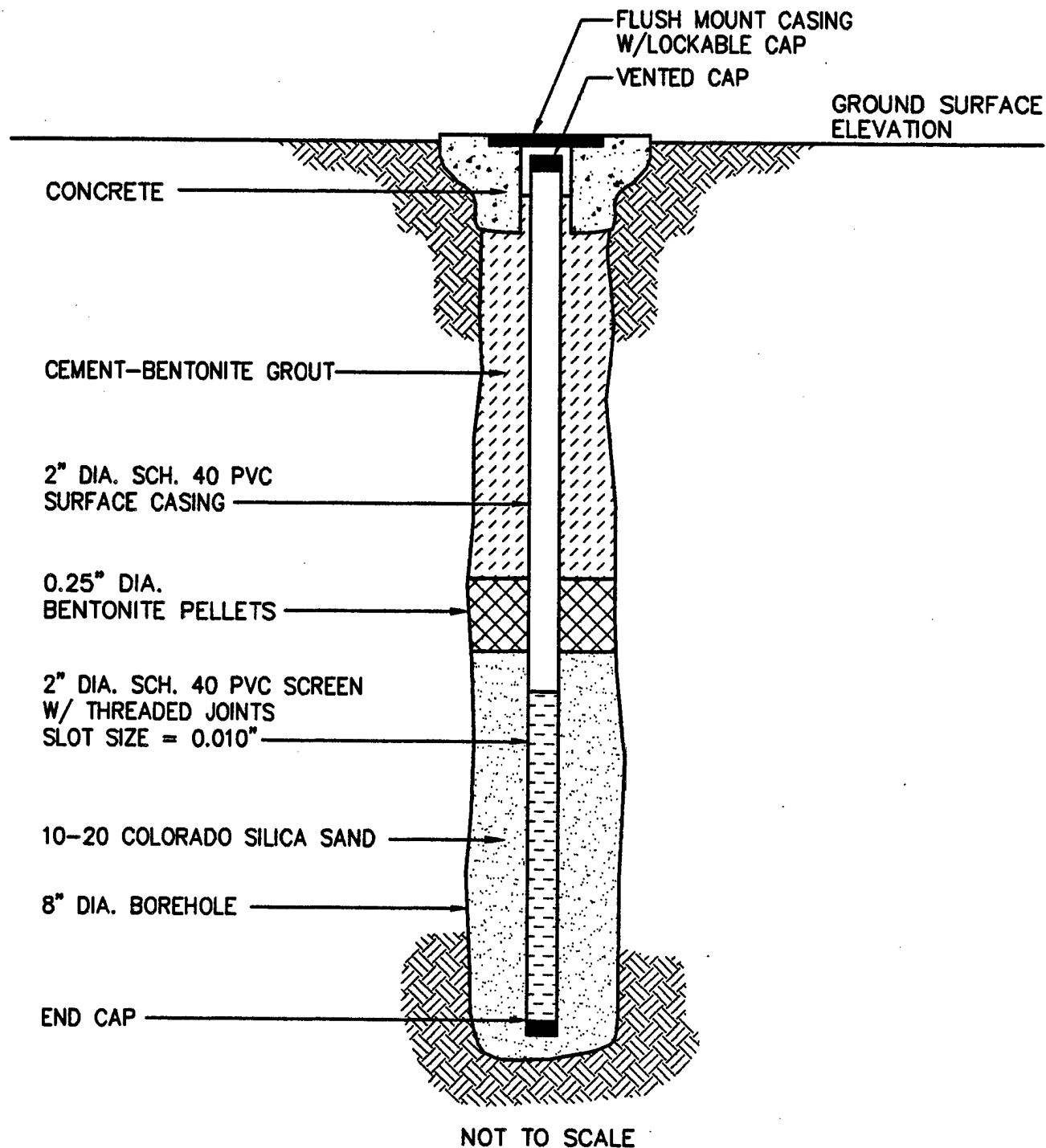


Figure A.2

TYPICAL MONITORING WELL COMPLETION DIAGRAM

EE/CA Work Plan
Risk-Based Approach to Remediation

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Well No. _____

Boring No. X-Ref: _____

MONITORING/SAMPLING POINT CONSTRUCTION SUMMARY

Survey Coords: _____ Elevation Ground Level _____

Top of Casing _____

Drilling Summary:

Total Depth _____

Borehole Diameter _____

Casing Stick-up Height: _____

Driller _____

Rig _____

Bit(s) _____

Drilling Fluid _____

Protective Casing _____

Well Design & Specifications

Basis: Geologic Log _____ Geophysical Log _____

Casing String (s): C = Casing S = Screen.

Depth	String(s)	Elevation
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Casing: C1 _____

C2 _____

Screen: S1 _____

S2 _____

Filter Pack: _____

Grout Seal: _____

Bentonite Seal: _____

Comments: _____

Construction Time Log:

Task	Start		Finish	
	Date	Time	Date	Time
Drilling	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
Geophys. Logging:	_____	_____	_____	_____
Casing:	_____	_____	_____	_____
_____	_____	_____	_____	_____
Filter Placement:	_____	_____	_____	_____
Cementing:	_____	_____	_____	_____
Development:	_____	_____	_____	_____
_____	_____	_____	_____	_____

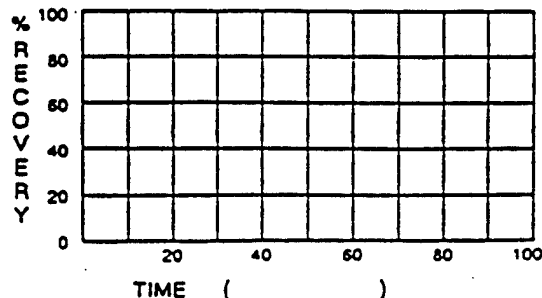
Well Development:

Stabilization Test Data:

Time	p H	Spec. Cond.	Temp (C)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Recovery Data:

Q= _____ S_o= _____



SITE NAME _____

W/C

SUPERVISED BY _____

Figure A.3
Well Installation Record

A.3.4.4 Sand Filter Pack and Annular Sealant

A graded sand filter will be placed around the screened interval and will extend at least 2 feet above the top of the screen. The sand filter will consist of 10-20 silica sand. An annular seal will be placed above the gravel pack using sodium bentonite pellets. The pellet seal will be a minimum of 2 feet thick and will be hydrated in place with potable water. The pellet seal will be overlain by a Portland[®] cement/sodium bentonite grout that will extend from the top of the pellet seal to approximately 3 feet bgs. The Portland[®] cement/sodium bentonite grout will consist of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the cement/bentonite will not exceed 8 percent by dry weight. The grout will be overlain with concrete to the ground surface. To reduce heaving of the newly-installed monitoring well caused by freeze-thaw processes, it is imperative that the uppermost concrete seal extend to at least the maximum frost line.

A.3.4.5 Flush-Mount Protective Cover

Each monitoring well will be completed with an at-grade (flush-mount) protective cover. In areas where pavement is present, the at-grade cover will be cemented in place using concrete which will be blended to the existing pavement. In areas where pavement is not already present, a 6-inch thick, 2-foot-diameter concrete pad will be constructed around the protective cover. In either case, the concrete immediately surrounding the well cover will be sloped gently away from the protective casing to facilitate runoff during precipitation events.

A.3.5 Well Development

Before any new well can be considered in proper condition for monitoring water levels or taking water samples, it must be developed. Development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen. If a well is grouted prior to development, well development will occur no sooner than 48 hours after grouting of the annulus is completed.

Well development will be accomplished using dedicated disposable bailers or a peristaltic pump. The bailer or pump will be lowered to the bottom of the well so that fines which have accumulated in the bottom are agitated and removed from the well in the development water.

Development will be continued until a minimum of three casing volumes of water have been removed from the well and the water pH, temperature, and specific conductivity have stabilized. Temperature, pH and specific conductivity will be monitored during development (one reading for each parameter per well volume). Pumping will continue until these parameters have stabilized to within 10 percent among three consecutive readings and the water is clear and free of fines. The pH and specific conductivity meters will be calibrated on a daily basis. The pH meter will be calibrated by laboratory-prepared standard solutions following the manufactures calibration procedures. The specific conductivity meter will be calibrated using laboratory-prepared known conductivity solutions. If the development water still is turbid after removal of three casing volumes, development will be continued until the water becomes clear or the turbidity of the water produced has been stable after the removal of several casing volumes.

The development procedure specifies that three casing volumes of water be removed from the well. However, some wells completed in marginal aquifers will go dry during well development prior to the recovery of three casing volumes. In these low-productivity wells, development

activity may have to be staged over a period of time to allow water to refill the well bore. In the event three casing volumes of water cannot be recovered, the water volume recovered will be noted in the development records.

All well purge water will be placed in 55-gallon drums supplied by the drilling subcontractor. Malmstrom AFB will be responsible for sampling, laboratory analysis and disposal of any contaminated or potentially contaminated purge and development water. Drums will be staged and temporarily stored onsite as directed by Malmstrom AFB personnel.

A.3.6 Well Development Records

A record of well development will be maintained for each well. The well development record will be maintained in a bound field notebook by the field hydrogeologist. Figure A.4 is an example of the well development record. A summary well development record form will be prepared for each well and submitted with the EE/CA report. Development records will include:

- Well number;
- Date and time of development;
- Development method;
- Predevelopment water level and well depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and well depth; and
- Field analytical measurements, including pH and specific conductivity.

A.3.7 Water Level Measurements

Water levels at all wells will be measured within a short time interval so that the water-level data are comparable. Water levels in the new wells will not be measured until they are developed and the water level has stabilized. The depth to water below the measurement datum will be made using an oil/water interface electric probe to the nearest 1/8 inch (0.01 foot). The oil/water interface probe will be decontaminated prior to use, and between each measurement, following the decontamination procedures presented in Section A.4.3. In addition, water level measurements will be made in all existing ground water monitoring wells at the site. This data will be used to calibrate the Bioplume II model and describe hydrogeologic characteristics.

A.3.8 Well Location and Datum Survey

The location and elevation of the new wells will be surveyed by a registered surveyor soon after well completion. Horizontal locations will be measured relative to the state plane coordinate system for the State of Montana. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface adjacent to the well casing, the measurement datum (top of the interior casing), and the top of the outer well casing will be measured relative to a USGS MSL datum. The ground surface elevation will be measured to the nearest 0.1 foot, and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

Figure A.4
Well Development Record

Page__ of__

Job Number_____
Location_____
Well Number_____

Job Name_____
By_____ Date_____
Measurement Datum_____

Pre-Development Information

Time (Start):

Water Level:

Total Depth of Well:

Water Characteristics

Color_____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material_____
pH_____ Temperature(^oF ^oC)_____
Specific Conductance(μ S/cm)_____

Interim Water Characteristics

Gallons Removed

pH

Temperature (^oF ^oC)

Specific Conductance(μ S/cm)

Post-Development Information

Time (Finish):

Water Level:

Total Depth of Well:

Approximate Volume Removed:

Water Characteristics

Color_____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material_____
pH_____ Temperature(^oF ^oC)_____
Specific Conductance(μ S/cm)_____

Comments:

A.3.9 Site Restoration

After well installation and sampling is complete, each well site will be restored as closely to its original condition as possible.

A.4 GROUND WATER SAMPLING

This section describes the scope of work required for collecting ground water samples at each of the 12 new wells and select existing, usable ground water monitoring wells. All water samples collected from ground water monitoring wells or bioventing wells will be obtained using either disposable bailers or a thoroughly decontaminated peristaltic pump. In order to maintain a high degree of quality control during this sampling event, the procedures described in the following sections will be followed.

Ground water sampling will be conducted by qualified ES scientists and technicians trained in the conduct of well sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed the work plan and this site-specific sampling and analysis plan prior to sample acquisition and will have a copy of both available onsite for reference.

Activities that will occur during ground water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity, including:
 - Protective cover, cap and lock,
 - External surface seal and pad,
 - Well stick-up, cap, and datum reference,
 - Internal surface seal,
 - Condition of bladder pump if present;
- Ground water sampling, including:
 - Water-level measurements,
 - Visual inspection of borehole water,
 - Well casing evacuation,
 - Sampling;
- Sample preservation and shipment, including:
 - Sample preparation,
 - Onsite measurement of physical parameters,
 - Sample labeling;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample disposition.

Detailed ground water sampling and sample handling procedures are presented in following sections.

A.4.1 Ground Water Sampling Locations

Ground water samples will be collected from a maximum of 12 newly installed wells and 3 existing wells using either a disposable bailer or a thoroughly decontaminated peristaltic pump.

A.4.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all recordkeeping materials will be gathered prior to leaving the office.

A.4.3 Equipment Decontamination

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This equipment includes the peristaltic pump and tubing, water-level probe and cable, oil/water interface probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof which will contact the samples. Based on the types of sample analyses to be conducted, the following decontamination protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent;
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade isopropanol; and
- Air dry the equipment prior to use.

All decontamination fluids will be contained in 55-gallon drums and treated on-site and disposed of as described in Section A.3.5. Any deviations from these procedures will be documented in the field scientist's field notebook and on the ground water sampling form. If pre-cleaned dedicated sampling equipment is used, the decontamination protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and therefore will not need to be cleaned in the field.

A.4.4 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite chemical measurements such as pH, electrical conductivity, and temperature.

A.4.5 Sampling Procedures

Special care will be taken to prevent contamination of the ground water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient decontamination of equipment between wells. To prevent such contamination, the peristaltic pump and water level probe and cable used to determine static water levels and well total depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section A.4.3. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves will be worn each time

a different well is sampled. Wells will be sampled sequentially from areas suspected to be least contaminated to areas suspected to be more contaminated.

The following paragraphs present the procedures that comprise ground water sample acquisition from all ground water sampling locations. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the ES field scientist's field notebook.

A.4.5.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well.

A.4.5.2 Water Level and Total Depth Measurements

Prior to removing any water from the well the static water level will be measured. An electrical water level probe will be used to measure the depth to ground water below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the well and the total well depth will be measured to the nearest 0.01 foot. Based on these measurements the volume of water to be purged from the well can be calculated.

Emphasis will also be placed on defining the probable areal extent of any remaining free fuel product that may act as a continuing source of contamination at the site. Free product can be physically identified during drilling and soil sampling and through the use of an oil/water interface probe. Moreover, ground water samples showing a benzene concentration equal to or in excess of 178 mg/L (10 percent of its maximum solubility in water) will be operationally defined as potential fringe areas to oily-phase contamination (or underlying significant residual soil contamination).

A.4.5.3 Well Purging

The volume of water contained within the well casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well. The pH, temperature, and specific conductivity will be monitored during well purging. Purging will continue until these parameters have stabilized to within 10 percent among three consecutive readings. All purge water will be placed in 55-gallon drums and treated on-site and disposed of as described in Section A.3.5. Disposable bailers or a thoroughly cleaned peristaltic pump will be used for well evacuation.

If a well is evacuated to a dry state during purging, the well will be allowed to recharge to 80 percent of its original water level and the sample will be collected as soon as sufficient water is present in the well to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to eventually obtain a sample of sufficient volume, will not be allowed.

A.4.5.4 Sample Extraction

Either disposable, polyethylene bailers or a thoroughly decontaminated peristaltic pump will be used to extract ground water samples from the well. Both types of extraction equipment will be lowered into the water gently to prevent splashing and extracted gently to prevent creation of

an excessive vacuum in the well. The sample will be transferred directly to the appropriate sample container. The water sample will be transferred from the bottom of the bailer using a bottom emptying device to allow a controlled flow into the sample container. Water for the peristaltic pump can be directly discharged into the sample container. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for well purge waters and staged on-site and disposed of as described in Section A.3.5.

A.4.6 Onsite Chemical Parameter Measurement

Dissolved oxygen (DO) measurements will be taken onsite using a meter with a downhole oxygen sensor. The DO meter will be decontaminated, prior to each use, following decontamination procedures described in Section A.4.3. DO measurements will be taken immediately following ground water sample acquisition. Where DO measurements will be taken in wells which have not been sampled, the well will be purged as described earlier prior to taking the DO measurement.

Because the pH, temperature, and specific conductance of a ground water sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis and the measured values will be recorded in the ground water sampling record.

A.4.7 Sample Handling

This section describes the handling of samples from the time of sampling until the samples arrive at the laboratory.

A.4.7.1 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the laboratory. The sample containers will be filled as described in Section A.4.5.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (ground water, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

A.4.7.2 Sample Preservation

The laboratory will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees centigrade (°C).

A.4.7.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the AFCEE-approved laboratory for this demonstration. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
 - Sample collector's name, address, and telephone number;
 - Laboratory's name, address, and telephone number;
 - Description of sample;
 - Quantity of sample; and
 - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition.

A.4.7.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling contractor after sample delivery to the analytical laboratory, and the other two copies will be retained at the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

A.4.7.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the ES field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
 - Sample appearance,
 - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Ground water sampling information will be recorded on a ground water sampling form. Figure A.5 shows an example of the ground water sampling record.

A.4.8 Laboratory Analyses

Laboratory analyses will be performed on all ground water samples and the required QA/QC samples (see section A.4.9). The analytical methods and detection limit requirements for this sampling event are listed in Table 4.1 in the body of the work plan.

Prior to sampling, arrangements will be made with the laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with laboratory protocol.

Figure A.5
Ground Water Sampling Record

SAMPLING LOCATION _____
SAMPLING DATE(S) _____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____
(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.
SAMPLE COLLECTED BY: _____ of _____
WEATHER: _____
DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED: ☐ UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: _____
INNER PVC CASING CONDITION IS: _____
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

- 1 ☐ EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____

- 2 ☐ WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____
- 3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____
- 4 ☐ WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
[] Pump, type: _____
[] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: _____ ° _____ Measured with: _____
pH: _____ Measured with: _____
Conductivity: _____ Measured with: _____
Other: _____

7 [] SAMPLE CONTAINERS (material, number, size):

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

[] Preservatives added:

Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
[] Container Lids Taped
[] Containers Placed in Ice Chest

10 [] OTHER COMMENTS:

Laboratory personnel will specify any additional QC samples and prepare bottles for all samples. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to shipping. Shipping containers, ice chests with adequate padding, and cooling media will be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratories.

A.4.9 Quality Assurance/Quality Control Samples

Field QA/QC procedures for ground water will include collection of field duplicates and rinseate, field and trip blanks, decontamination of the water level probe, use of analyte-appropriate containers, and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., ground water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

Ground water QA/QC sampling will include duplicates for up to one well (i.e., frequency of 10 percent), rinseate blanks for up to one well (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual cooler sent to the analytical laboratory. The procedures for the collection of field QA/QC samples are described in Section A.6. The laboratory should plan to conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

A.5 AQUIFER TESTING

Slug tests will be conducted at four locations to estimate the hydraulic conductivity of the shallow saturated zone. Slug tests will be completed using ground water monitoring wells MW-18, and three new monitoring wells to be installed during the field investigation. Pumping tests will not be conducted because large quantities of potentially contaminated water is generated and must be treated or disposed. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests are best used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; in this field investigation both methods will be used in sequence.

A.5.1 Definitions

- Hydraulic Conductivity (K). A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- Transmissivity (T). A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- Slug Test. Two types of testing are possible; a rising head or falling head test. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of

water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.

- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

A.5.2 Equipment

The following equipment is needed to conduct a slug test:

- Teflon[®], PVC, or metal slugs,
- One-quarter-inch nylon or polypropylene rope,
- Oil/water interface electric water level indicator,
- Pressure transducer/sensor,
- Field logbook/forms, and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger, In-Situ, Inc. Model SE1000B or equal).

A.5.3 Test Methods, General

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Prior to testing, the monitoring well must be thoroughly developed as described in Section A.3.5 and water levels allowed to stabilize. Slug testing will proceed only after water level measurements show that static water level equilibrium has been achieved. During the slug test, the water level change should be influenced only by the introduction (or subtraction) of the slug volume. Other factors, such as inadequate well development, extended pumping, etc., may lead to inaccurate results. It is up to the ES field hydrogeologist to decide when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of the slug test, using the procedures described in Section A.4.3.

A.5.3.1 Falling Head Test

The falling head test is the first step in the two-step slug-testing procedure. The following steps describe the falling head test.

1. Decontaminate all down-hole equipment, following the decontamination procedures described in Section A.4.3, prior to initiating the test.
2. Open the well. Where wells are located within the 100-year flood plain, and equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow

the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.

3. Prepare the Aquifer Test Data form (Figure A.6) with entries for:

- Borehole/Well number;
 - Project number;
 - Project name;
 - Aquifer testing team;
 - Climatic data;
 - Ground surface elevation;
 - Top of well casing elevation;
 - Identification of measuring equipment being used;
 - Page number;
 - Static water level;
 - Date; and
 - Time intervals (0,1,3,5,7,9,10, and 12 minutes and every 3 minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).
4. Measure the static water level in the well to the nearest 0.01 foot.
5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by making periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
6. Lower the decontaminated slug into the well to just above the water level in the well.
7. Turn on the data logger, and quickly lower the slug below the water table being careful not to disturb the pressure transducer. Follow the owners' manual for proper operation of the data logger.
8. Terminate data recording when the water level stabilizes in the well.

A.5.3.2 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the static water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the Owners Manual for proper operation of the Data Logger.
3. Terminate data recording when the water level stabilizes in the well. Remove the pressure transducer from the well and decontaminate.

Page _____ of _____

Well No. _____ Distance from pumping well _____ Type of test: _____ Test No. _____

Measuring equipment

Time Data	Water Level Data	Discharge Data	Comments on factors affecting test data
Pump on: Date _____ Time _____ (r) Pump off: Date _____ Time _____ (r) Duration of aquifer test: Pumping _____ Recovery _____	Static water level _____ Measuring point _____ Elevation of measuring point _____	How Q measured _____ Depth of pump/wr line _____ Previous pumping? Yes _____ No _____ Duration _____ End _____	

[illegible]

A.5.3.3 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV[®] and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The standard slug test form (Figure A.7) is based on equations and test methods developed by Hvorslev (1951). Figure A.8 is the Bouwer and Rice Analysis Data Form. Figure A.9 contains the dimensionless parameters A, B, and C used for the Bouwer and Rice Analysis.

A.6 SURFACE WATER SAMPLING PROCEDURES

Surface water flow measurements will be collected from four locations along the drainage ditches on either side of Flightline Drive. The locations will be staked and surveyed and water depth in the ditches will be recorded at time of sampling. In the event that there is insufficient water in the ditches to collect samples, sediment grab samples will be taken from the bottom of the ditch and analyzed with soil samples from drilling activities at the site.

Samples will be collected so as not to cause cross-contamination. Background (i.e., upgradient) samples will be collected first. The surface water sample at each station will be collected so as to minimize the amount of suspended solids in the water sample. Surface water will be handled and transported in the same manner as ground water and soil samples. All samples will be placed in the appropriate containers with Teflon[®]-lined caps, and stored on ice in an insulated cooler.

Surface water samples will be collected by submerging unpreserved sample containers in the ditch. Sample bottles that contained preservative will be filled by first filling an unpreserved sample bottle and transferring the sample into the preserved bottle. Surface water temperature, pH, and specific conductance will be measured at each sampling point.

Physical environmental information observed at each sampling site will also be recorded in the field notebook. This information will include the sample station location, the width, depth, and flow rate of the stream, surface water conditions such as floating oil, color, or debris, and the location of any nearby discharge pipes, sewers, or tributaries.

A.7 FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on field sampling, QA/QC samples, including trip blanks, field blanks, decontamination water blanks, equipment rinseate blanks, and field duplicates will be collected. Each type of QA/QC sample is described below.

A.7.1 Trip Blanks

A trip blank is defined as a sample bottle filled by the laboratory with analyte-free laboratory reagent-grade water, transported to the site, handled like a sample but not opened, and returned to the laboratory for analysis. One trip blank will accompany every cooler of soil and water samples sent to the laboratory. Trip blanks are analyzed only for Method SW8020.

A.7.2 Decontamination Water Blank

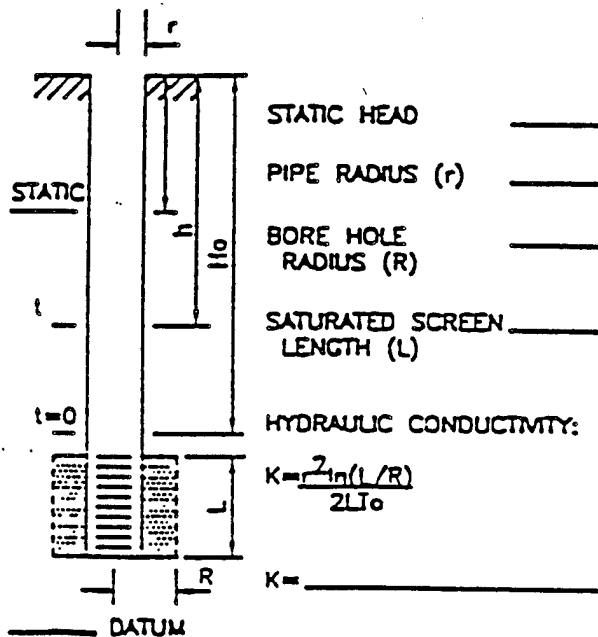
A decontamination water blank is designed to check the purity of potable water used for equipment decontamination during the field operation. One decontamination water blank will be collected for each water source used during the field work. Decontamination water blanks are

Figure A.7
Standard Slug Test Form/Hvorslev Analysis

HVORSLEV'S METHOD FOR K

PROJECT _____
WELL NUMBER _____
DATE _____

LOCATION _____
ELEVATION _____



TIME (MIN)	WATER DEPTH (FT)	RECOVERY TO STATIC ± (WATER DEPTH-STAT)	$\frac{h}{H_o}$
STATIC			
00		(H _o)	1.00
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	

K = _____ FT/MIN K = _____ FT/DAY K = _____ CM/SEC

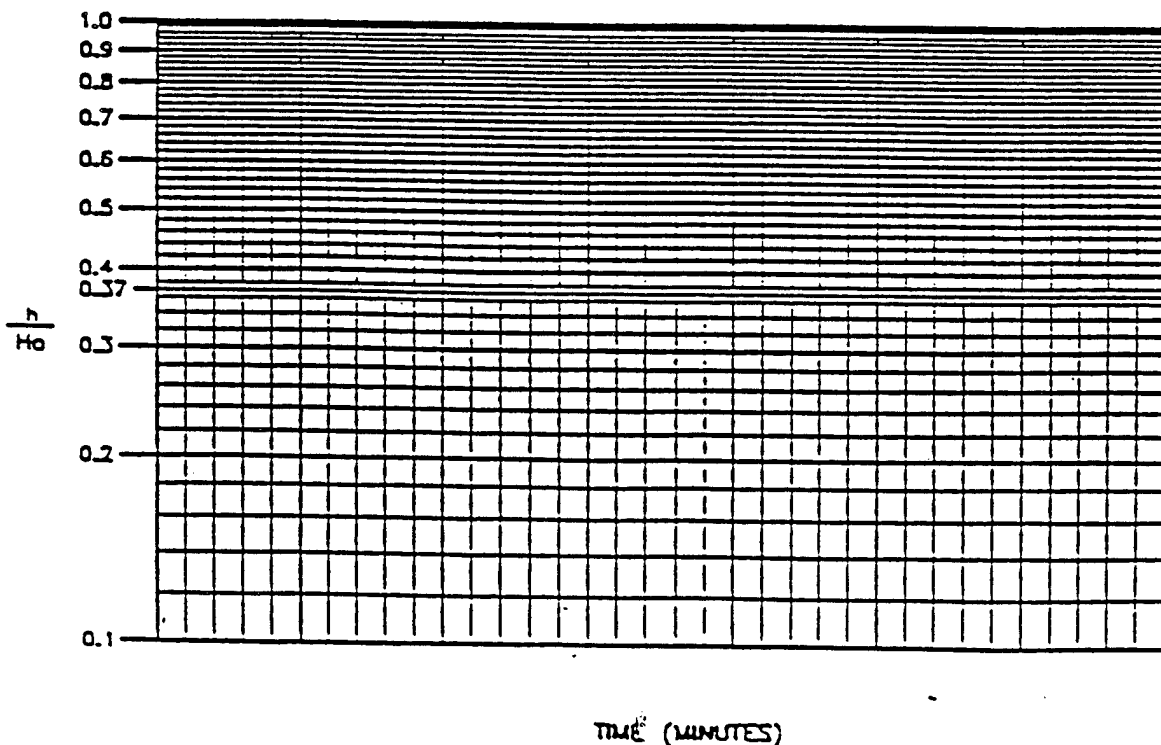
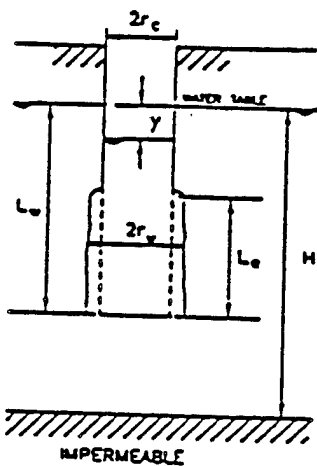


Figure A.8
Bouwer and Rice Analyses Data Form

BOUWER AND RICE METHOD FOR K

(Reference: GROUNDWATER - May, June 1989, Vol. 27, No. 3)

PROJECT _____ LOCATION _____
WELL NUMBER _____ ELEVATION _____
DATE _____



STATIC HEAD _____

PIPE RADIUS (r_c) _____

BORE HOLE

100-443887-100

SATURATED SCREEN _____
LENGTH (L_s)

WELL DEPTH _____

HYDRAULIC CONDUCTIVITY:
(ASSUME $L_x = H$)

$$K = \frac{(r_c) \ln(R_c/r_w)}{2L_e} \quad \begin{bmatrix} 1 \\ t \end{bmatrix} \ln \begin{bmatrix} y_0 \\ y_1 \end{bmatrix}$$

K=_____

[illegible]

K_{∞} _____ FT/MIN K = _____ FT/DAY K = _____ CM/SEC

WHERE: $r_c = [(1-n)r_c^2 + nr_c^2]$
 $n = \text{POROSITY } (\sim 30\%)$

* If, TAKES INTO ACCOUNT THE RADII OF THE WELL AND THE THICKNESS AND POROSITY OF THE GRAVEL PACK. POROSITY OF THE GRAVEL PACK (α) IS ESTIMATED AT JOE. USE THIS EQUATION IF A GRAVEL PACK IS PRESENT.

$$\text{ASSUME } L_w = H: \ln \frac{R_x}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{(L_w/r_w)} \right]^{-1} \quad C = 1.4$$

ASSUME $L_{\infty} = 0$: $\ln \frac{R_p}{r_w} = \left[\frac{1.1}{\ln(L/r_w)} + \frac{A + B \ln[(H-L)/r_w]}{(L/r_w)} \right]^{-1}$

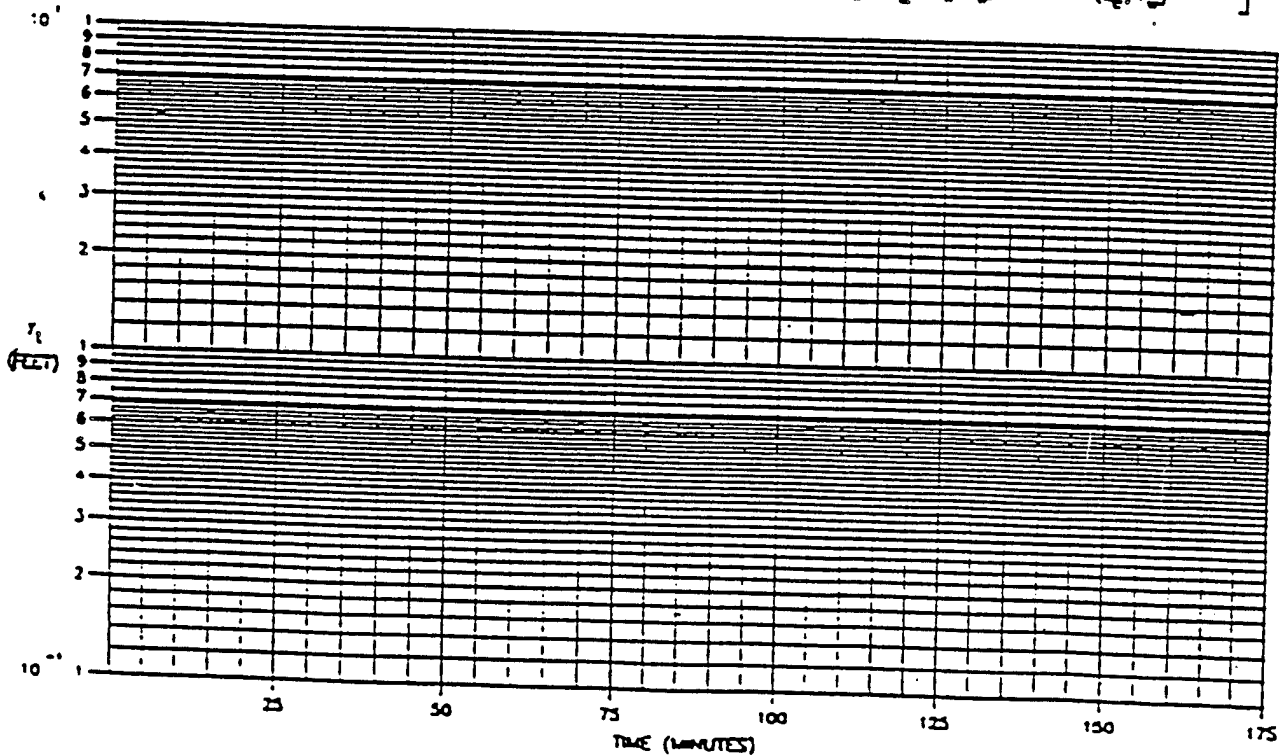
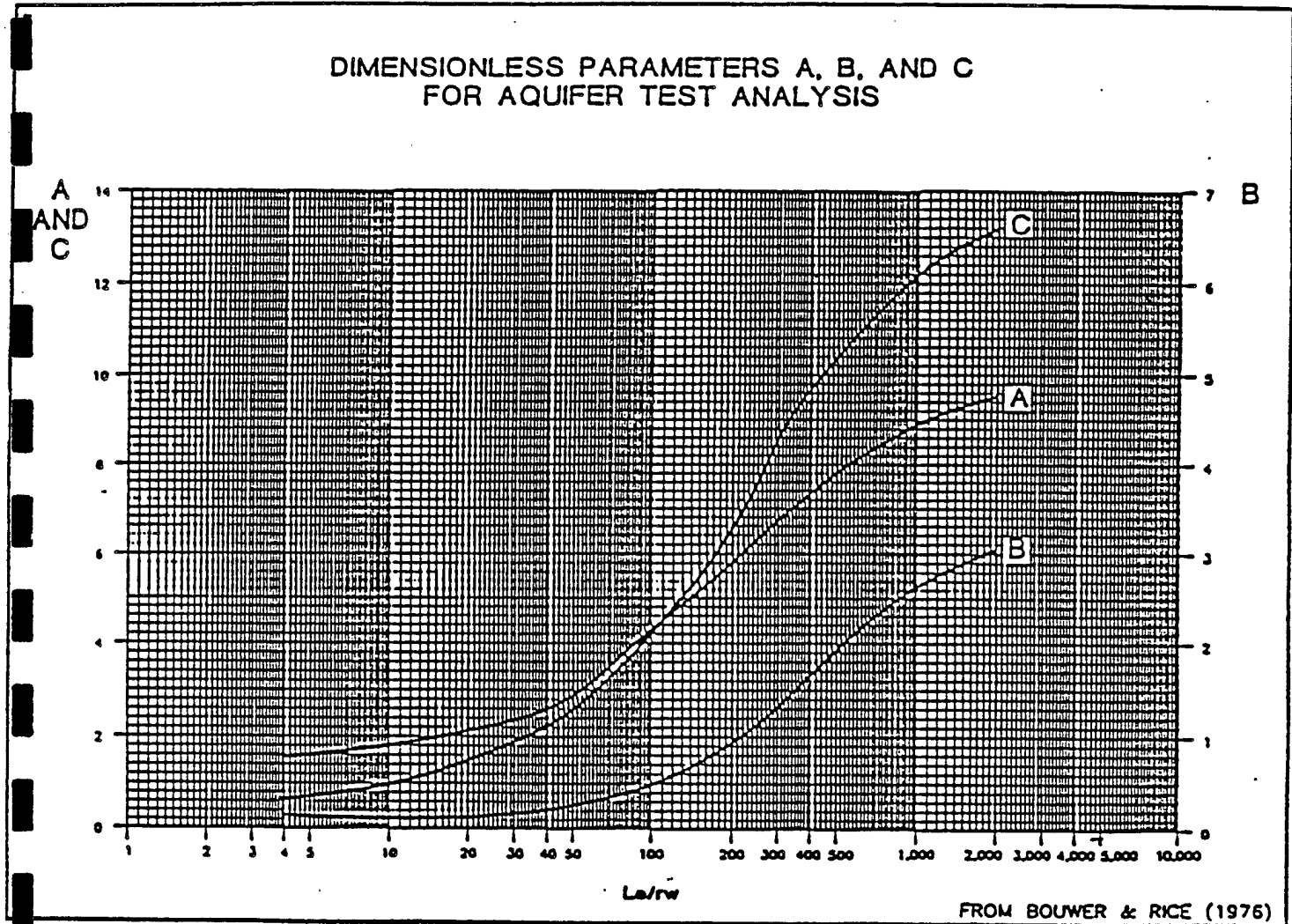


Figure A.9
Bouwer and Rice Analyses Dimensionless Parameters



collected by filling the appropriate sample container directly from the potable water source. Decontamination water blanks are labeled, preserved, handled, and shipped in the same manner as an environmental water sample. The blank will be analyzed for the same analytes and parameters as the environmental samples.

A.7.3 Field Blanks

A field blank is designed to assess the effects of ambient field conditions on sample results. A field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. One field blank will be analyzed for soil and one for water. The field blank will be analyzed for the same analytes and parameters as the environmental samples.

A.7.4 Equipment Rinseate Blanks

Equipment rinseate blanks will be collected from field equipment such as continuous core barrels. Equipment rinseate blanks are prepared by pouring distilled water over field equipment that has been decontaminated. The rinseate water is then collected, transferred to a sample bottle, and analyzed at the laboratory. The results of these sample analyses indicate how well the sampling equipment was decontaminated.

A.7.5 Field Duplicate Samples

A field duplicate is defined as two or more samples collected independently at the same sampling location during a single act of sampling. Soil samples are mixed and divided into two equal parts for analysis. Duplicates of water samples will be collected by filling additional sample containers at each duplicated sampling event.

Field duplicates will be indistinguishable from other samples by the laboratory. One complete sample set will be identified with a coded identifier, which will be in the same format as other identifiers used with this matrix. Both the coded and actual sample identifiers will be recorded in the field notebook. The coded identifier will be used on the chain-of-custody forms.

1.0 INTRODUCTION

This addendum modifies the existing *Program Health and Safety Plan for Risk-Based Remediation Demonstrations* (Engineering-Science, Inc., 1994), for conducting progressive site investigations at United States Air Force facilities under contract number F41624-93-C-8044.

This addendum to the health and safety plan was prepared to address the upcoming field tasks at Malmstrom AFB, Montana. The site to be investigated through a risk-based remediation approach will include Pumphouse #2 within IRP Site PS-3. This investigation will only focus on Pumphouse #2 which consists of a pumphouse (Building 245), electrical control building (Building 246), one 2,000-gallon and six 50,000-gallon USTs.

The demonstration to be conducted at Pumphouse #2 of an innovative technology is being sponsored by the Air Force Center for Environmental Excellence (AFCEE) at Brooks AFB, Texas under Contract F41624-93-C-8004, "Risk-Based Approach to Fuel Spill Remediation."

Included or referenced in this addendum are site-specific descriptions, history and proposed activities; hazard evaluation of known or suspected chemicals; personal protective equipment (PPE); personnel decontamination procedures; site-specific training and medical monitoring requirements; air monitoring; site control procedures; employee exposure monitoring; and emergency response procedures.

In addition, all ES field team members will be properly trained in the use, care, disposal, limitations, and maintenance of personal protective equipment (PPE).

Site hazards will be assessed and communicated to the field team members to determine if hazards are present, or are likely to be present, which may necessitate the use of PPE.

2.0 SITE DESCRIPTION, HISTORY, AND SITE-SPECIFIC ACTIVITIES

The site description, history, and pilot test activities to be performed at this site are outlined in the site-specific work plan entitled *Work Plan for Engineering Evaluation/Cost Analysis In Support of Risk-Based Approach to Remediation at Pumphouse #2 at Malmstrom Air Force Base, Montana*. A brief listing of planned site-specific activities follows.

Services to be performed by ES include sampling of soil, soil gas, surface waters, ground water, and surficial soils, if appropriate.

A sufficient number of samples from background and contaminated areas will be collected and analyzed for individual and indicator compounds to accurately assess the risk to human health and the environment posed by the site and to demonstrate the attainment of final cleanup levels.

In order to facilitate implementation of the site evaluation, ES may be assisted by subcontractors to perform additional drilling and laboratory analysis of environmental samples.

In addition to the drilling vehicles and heavy equipment traditionally used on ES projects, a hydraulically driven Geoprobe® system may be used at the Malmstrom AFB Pumphouse #2 site to collect soil gas, soil, and groundwater samples. A hydraulic press has been mounted on the bed of an ES pick-up truck with power supplied to the cylinder via a power-take-off on the truck's engine.

A list of the manufacturer's operating safety instructions to be followed by all ES subcontract personnel on this project is provided below:

- Never operate controls without proper training.
- Always take vehicle out of gear and set emergency brake before engaging remote ignition.
- If vehicle is parked on a loose or soft surface, do not fully raise rear of vehicle with probe foot, as vehicle may fall or move, causing injury.
- Always extend the probe unit out from the vehicle and deploy the foot to clear vehicle roof line before folding the probe unit out.
- Operators should wear OSHA approved steel toed shoes and keep feet clear of probe foot.
- One person only should operate the probe machine and the assembly - disassembly of probe rods and accessories.
- Never place hands on top of a rod while it is under the machine.
- Turn off the hydraulic system while changing rods, inserting the hammer anvil, or attaching accessories.
- Operator must stand to the control side of the probe machine, clear of probe foot and mast, while operating controls.
- Wear safety glasses at all times during the operation of this machine.
- Never exert down pressure on the probe rod so as to lift the machine base over six inches off the ground.
- Never exert down pressure on a probe rod so as to lift the rear tires of the vehicle off the ground.
- Always remove the hammer anvil or other tool from the machine before folding the machine to the horizontal position.
- The vehicle catalytic converter is hot and may present a fire hazard when operating over dry grass or combustibles.
- Geoprobe® operators must wear hearing protection. OSHA approved hearing protection for sound levels exceeding 85 dB is mandatory.
- The location of buried or underground utilities and services must be known before starting to drill or probe.
- Shut down the hydraulic system and stop the vehicle engine before attempting to clean or service the equipment.
- Accidental engagement of this machine may cause injury.

3.0 SITE-SPECIFIC EMPLOYEE TRAINING AND MEDICAL MONITORING REQUIREMENTS

See Section 4 of the program health and safety plan (Engineering-Science, Inc., 1994) for guidance.

4.0 HAZARD EVALUATION

4.1 Chemical Hazards

General hazards are addressed in the program health and safety plan. Site-specific hazards are identified below.

Chemicals known or suspected to occur at Pumphouse #2 include petroleum hydrocarbon fuel components benzene, toluene, ethylbenzene, and xylenes (BTEX) as well as chlorobenzene, naphthalene, phenols and carbazole.

Health hazard qualities for these compounds are presented in Table 5.1 of the program health and safety plan.

4.2 Physical Hazards

Potential physical hazards at this site include risks associated with the installation/operation of bioventing equipment such as underground utilities; overhead utilities; drilling activities; electrical equipment; heavy equipment; motor vehicles; slip, trip, and fall hazards; noise; and heat stress.

Protection standards for physical hazards are contained in Section 7 of the program health and safety plan.

5.0 AIR MONITORING

During operations that disturb site soils, a hydrocarbon detector or photoionization detector (PID or equivalent) will be used to measure ambient air concentrations in the worker breathing zone. As shown in the attachment, if the hydrocarbon detector measures total fuel vapor concentrations of 0-5 ppm, site workers will continue air monitoring in a Level D ensemble. If total fuel vapor concentrations reach 5-25 ppm for more than 30 seconds, and benzene concentrations exceed 1 ppm, site workers will evacuate the site or upgrade to Level B ensemble, if trained to do so. If benzene concentrations are less than 1 ppm, the site crews may continue in Level D ensemble with periodic air monitoring. If total fuel vapor concentrations reach 25-50 ppm for greater than 30 seconds and benzene concentrations exceed 1 ppm, site crews will evacuate the site or upgrade to Level B ensemble. If benzene concentrations are less than 1 ppm and vapors are in the range of 25-50 ppm, site workers will don full facepiece air-purifying respirators (APR) equipped with organic vapor cartridges (NIOSH approved), and continue periodic air monitoring. If total fuel vapor concentrations reach 50-500 ppm for greater than 30 seconds, the site crews will evacuate the site or upgrade to Level B ensemble. If total fuel vapor concentrations exceed 500 ppm for greater than 30 seconds, site crews will evacuate the site.

Before work can be performed in Level B respiratory protection the project manager must be notified. He will initiate the change order process with the Air Force or decide to halt activities at that site. (Level B operations require approval from

corporate health and safety.) The site health and safety officer will determine whether it is safe to continue activities without respiratory protection or assign an upgrade to Level C protection. Flammable vapor monitoring will be conducted if potentially flammable atmospheres occur. See Sections 8 and 11 of the program health and safety plan for specific guidance.

6.0 SITE CONTROL PROCEDURES

Site control measures will be followed in order to minimize potential contamination of workers, protect the public from potential site hazards, and control access to the sites. Site control involves the physical arrangement and control of the operation zones and the methods for removing contaminants from workers and equipment. See Section 9 of the program health and safety plan for guidance.

Specific site control procedures at this site will include establishment of site work zones whenever employees are wearing respiratory protection. Unauthorized personnel will be restricted from entering the immediate work area.

7.0 PERSONAL PROTECTIVE EQUIPMENT

It is anticipated that Level D respiratory protection, with a contingency provision for the use of Level C will be used at these sites. Additional guidelines for the selection of respiratory protection at these sites are contingent upon the discovery of benzene vapors in the worker breathing zone while performing site activities. Site crews will assess the need for respiratory protection, or PPE, as applicable.

Protective clothing to be used at these sites includes:

- Hard hats
- Safety glasses
- Suits (Tyvek® or Saranex®)
- Respirator, if needed (APR with combination organic vapor/HEPA cartridges)
- Inner gloves (Latex or Vinyl)
- Outer gloves (Nitrile or Neoprene)
- Boots (Safety boots with latex boot covers)
- Other

8.0 PERSONNEL DECONTAMINATION PROCEDURES

See Section 10 of the program health and safety plan for general procedures and guidance. Of the compounds being used for decontamination, methanol is considered potentially hazardous. Methanol is volatile and flammable. The PEL for methanol is 200 ppm. An STEL of 250 ppm for 15 minutes is allowed for methanol. Exposure of the skin to methanol can result in skin burns and/or skin absorption.

The PEL for methanol can be reached when the PID is reading 8 ppm. This is because the relative response factor of methanol is 0.04 when the PID is equipped with a standard 10.2 or 10.6 eV lamp and is calibrated with 100 ppm isobutylene. Therefore, air monitoring should be performed when decontaminating equipment with

methanol. If a respirator is needed during such operations, appropriate cartridges should be used. Nitrile gloves and chemical goggles should be used.

Methanol will be in plastic bottle jackets during use in the field. These bottle jackets will be properly labeled, and during transport into the field will be cushioned inside a larger locked-lid plastic carrying container that is secured in the vehicle. All chemical wastes (waste methanol) generated during decontamination will be collected in an empty manufacturer's chemical bottle with a bottle jacket, labelled with contents, dated, and transported as described above. Call the point-of-contact at the Air Force Base for proper disposal procedures and transport to the hazardous materials storage area.

9.0 EMPLOYEE EXPOSURE MONITORING

Employee exposure monitoring will be conducted on this site in accordance with Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910) and the program health and safety plan.

10.0 EMERGENCY RESPONSE PLAN

10.1 Safe Distances and Places of Refuge

Prior to initiation of field activities, the field crew shall decide on safe distances to retreat to and select a place of refuge in the event of an emergency. This information shall be provided to all pilot test field personnel during weekly or daily site-specific safety briefings. All other guidelines established in the program health and safety plan for emergency planning, training, recognition, etc. shall be followed.

10.2 Emergency Information

Listed below are the name and phone numbers for medical and emergency services for this project.

Hospital	Deaconess Hospital
Address	1101 Twenty Sixth Street, South Great Falls, MT 59405
Phone	(406) 761-1200

Description of the route to the hospital:

From Pumphouse #2 exit the Malmstrom AFB west gate and follow to the 57th Street bypass (Byp. 87). Take a left on Byp. 87 and follow to Route 200. Go right on Route 200 and follow to 26th Street South. Go left on 26th Street South, and follow to Deaconess Hospital.

Other Emergency Numbers:

Fire Department 911

Security Police 911

Ambulance 911

Crime 911

Program Health and Safety Manager:

Tim Mustard work: (303) 831-8100

home: (303) 450-9778

Project Manager:

Doug Downey work: (303) 831-8100

home: (303) 670-0512

11.0 REFERENCES

Engineering-Science, Inc. 1994. *Work Plan for Engineering Evaluation/Cost Analysis In Support of Risk-Based Approach to Remediation at Pumphouse #2 Malmstrom Air Force Base, Great Falls, Montana.*

Engineering-Science, Inc. 1994. *Program Health and Safety Plan for the Risk-Based Remediation Demonstration.* Denver, Colorado.